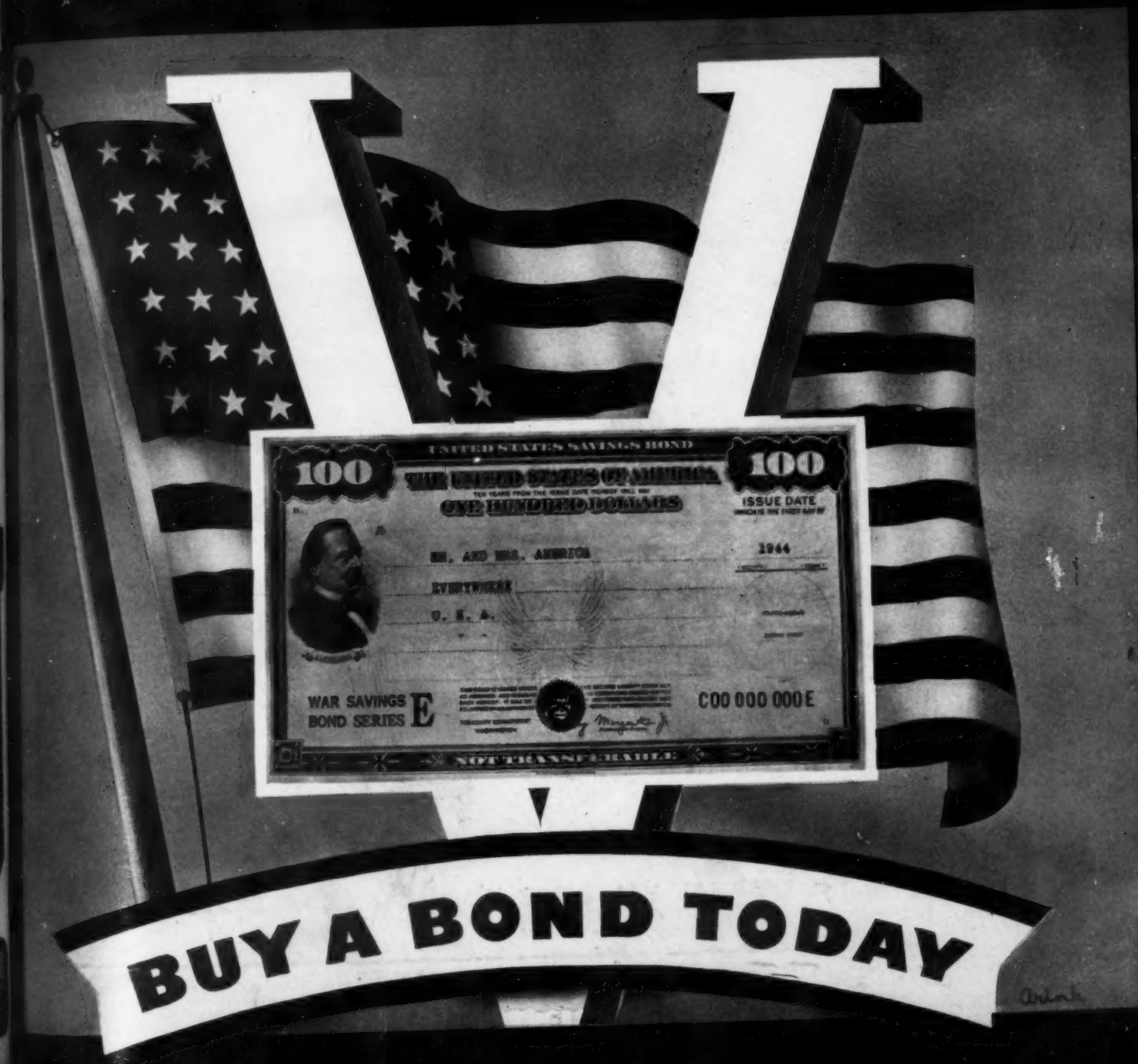
WATER WORKS & SEWERAGE



FAST DELIVERY... QUICKER INSTALLATION

on Chapman Standard

SLUICE GATES

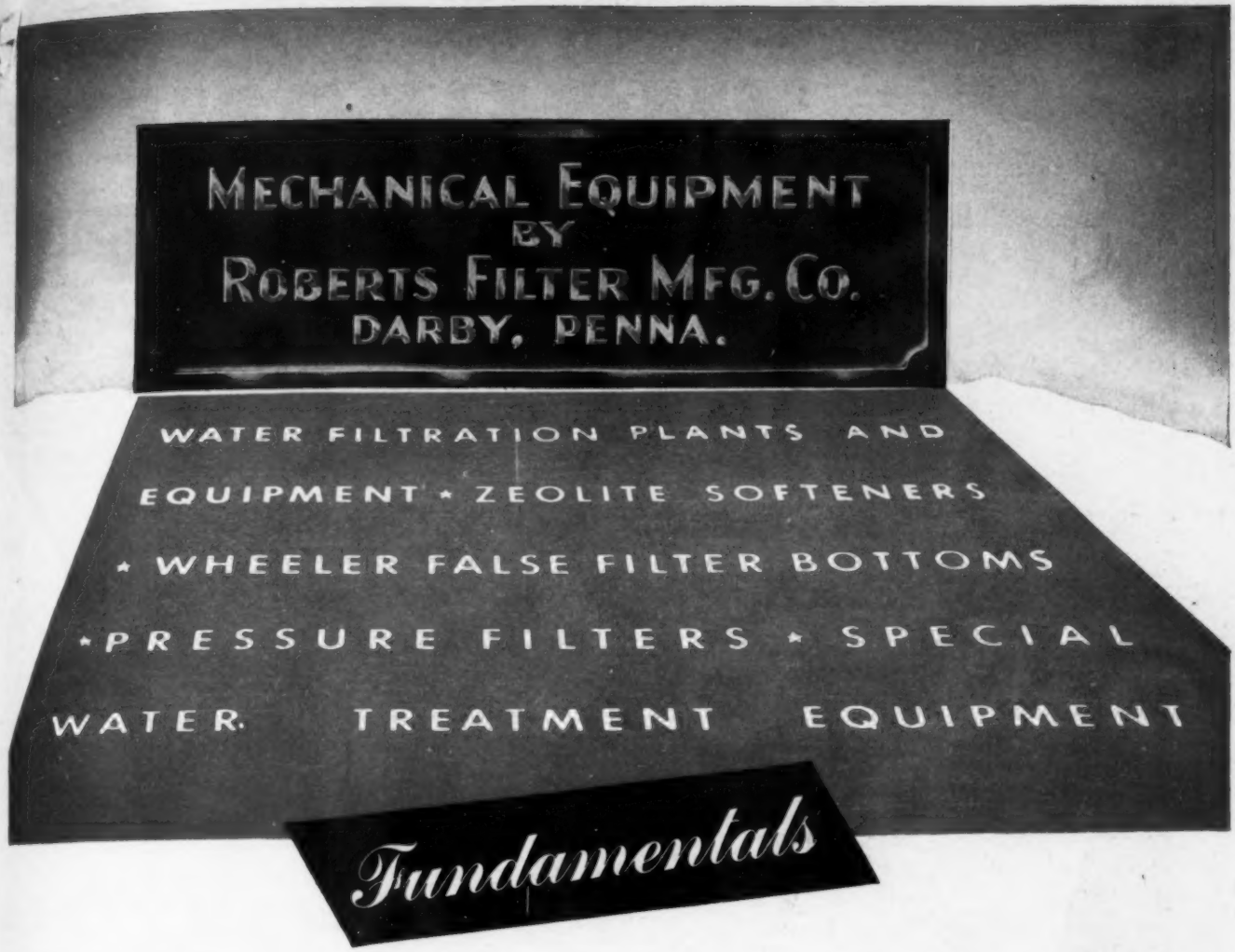
From our large collection, you can usually get the type and size of gate you need—without the expense or waiting for specially built equipment.

And Chapman gives you quicker installation because interchangeable stems and couplings need not be match-marked.

Chapman can also give you any type of operating control you may desire . . . manual, hydraulic cylinder, or Motor Unit. We'll gladly send you a copy of Chapman's Sluice Gate Handbook which gives complete information, dimensions, and specifications—write us for it *today*.

THE CHAPMAN VALVE MFG. CO., INDIAN ORCHARD, MASS.

WATER WORKS & SEWERAGE, June, 1944. Volume 91. Number 6. Published monthy by Gillette Publishing Co., 330 South Wells Street, Chicago Ill. Single copy, 25c, except this issue, 75c. Subscription rate, United States, $2.00 per year; Canada, $2.00 per year; Foreign, $3.00 per year. Entered as Second Class Matter, June 2, 1931, at the Post Office at Chicago, Ill., under act of March 3, 1879.



The reputation of Roberts Filter Company has been established on the fact that we are first of all, capable engineers. We have never deviated from this policy, regardless of the size of a job or its relative cost.

We have always operated under the assumption that those people for and with whom we work—expect us to have and to use freely our knowledge, insight, and long experience for the most efficient solution to their particular problems. Our entire personnel has been built up over a 30 year period to assure this participation-engineering to that degree required by specific circumstances.

The result of this type of thinking is evidenced in the hundreds of major projects and thousands of smaller installations for water treatment which are today operating with the Roberts nameplate of dependability upon them.

CONSULTING ENGINEERS

Many of the nation's leading consultants on water problems are using the facilities of Roberts Filter Company to aid in the detailed planning of present or future projects under their supervision. You will find the Roberts organization well informed, dependable, and cooperative in every way.

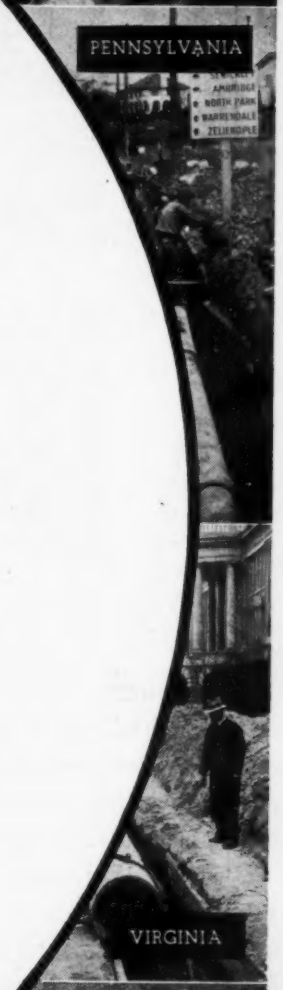
ROBERTS FILTER MANUFACTURING CO.

607 COLUMBIA AVENUE • DARBY, PENNSYLVANIA

THOUSANDS
TRANSITE PIPE
OHIO
CALIFORNIA
KANSAS
TEXAS
NEW JERSEY
ARIZONA
NEVADA
MISSOURI
MICHIGAN
"Blueprint Now!"
ONE WAY to provide immediate jobs for our fighting men when they return—and at the same time permanently benefit our cities, towns and villages—is through the improvement and expansion of our water and sewerage systems. Such a program, to be effective, must be ready to put into operation as soon as wartime restrictions are lifted.
That means getting the planning done now. As an aid to post-war planners, the Committee on Water and Sewage Works Development has prepared a booklet entitled "Blueprint Now!" If you have not received a copy, one may be obtained by writing the Committee at Suite 2110, 500 Fifth Avenue, New York 18, New York.
Blueprint Now!

OF MILES OF

... are providing efficient, dependable, economical water transportation throughout the nation



IN THE THOUSANDS OF MILES of Johns-Manville Transite Pipe in service today, you will find installations of almost every size and type. In big cities, small villages, in military camps and bases both here and abroad, Transite Pipe is serving efficiently in the transmission and distribution of water.

There are definite reasons for this wide acceptance. Made of asbestos and cement, Transite Pipe provides these important advantages:

Easy Handling. Light-weight Transite Pipe requires fewer men for handling. Only the larger sizes need mechanical handling equipment.

Tuberculation No Problem. Non-metallic in composition, Transite cannot tuberculate. Its initial high-flow coefficient (C=140) can never be reduced by tuberculation.

Low Maintenance. Made of asbestos-cement, Transite's corrosion-resistance and maintained strength contribute to its low maintenance costs.

Tight, Flexible Joints. Wide sweeps can be made with straight lengths because the Simplex Coupling stays tight even when the line is deflected as much as 5° at each joint.

Rapid Assembly. Even unskilled crews form tight joints easily, quickly with the Simplex Coupling.

For the complete facts, write to Johns-Manville for Transite Pipe Booklet TR-11A. For details on Transite Sewer Pipe for more efficient sewage disposal systems, ask for TR-21A. Johns-Manville, 22 E. 40th St., New York 16, New York.

TRANSITE PIPE IS AGAIN AVAILABLE FOR PROMPT SHIPMENT

JOHNS-MANVILLE

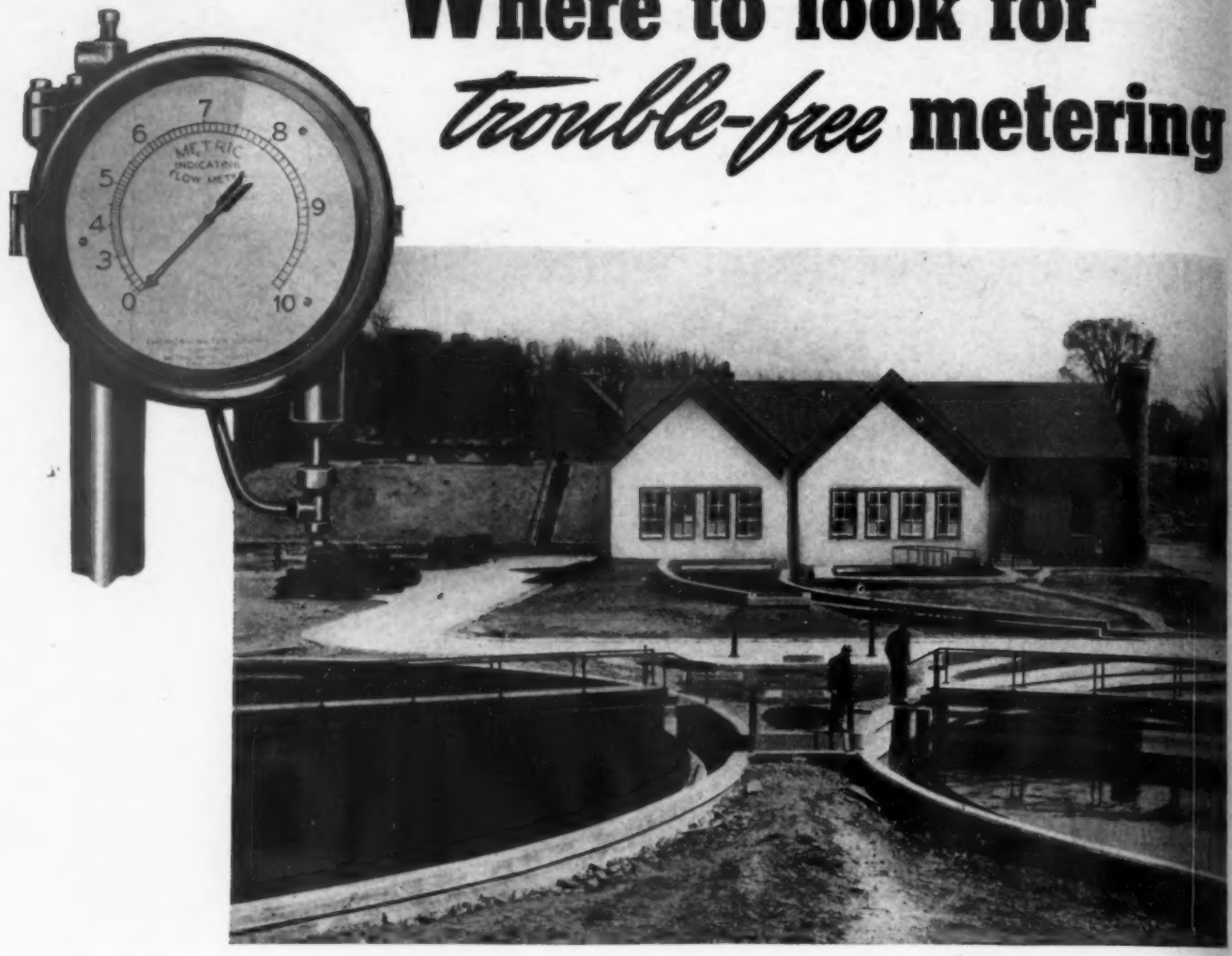
Asbestos

TRANSITE PIPE

FOR EFFICIENT, ECONOMICAL WATER AND SEWER LINES

JOHNS-MANVILLE JM PRODUCTS

Where to look for *trouble-free* metering



● ● ● Simplicity of basic design is a characteristic of **American** meters in both displacement metering of sewage gas and orifice measurement of gases and liquids.

In orifice metering, whether by indicating, recording or integrating instruments, you will find fewer moving parts to wear and get out of adjustment, and every provision for easier inspection. These meters are serving in not only the sewage field and the most modern process industries plants in the country, but in the remote parts of the world where ruggedness and ease of maintenance are of even weightier consequence.

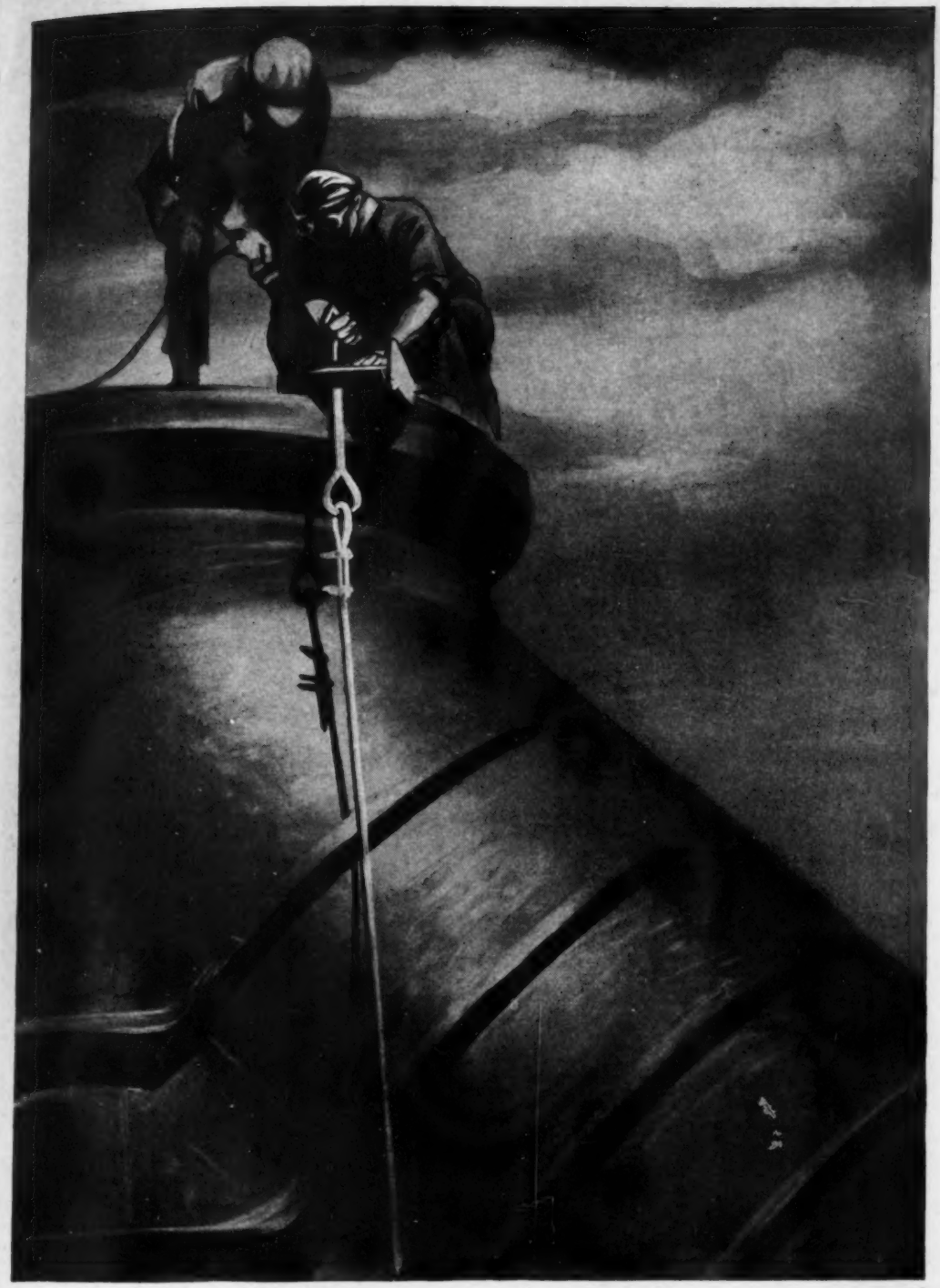
In the field of displacement metering of sewage gas, the **American** Ironcase Meter with its rugged one-piece body eliminating gaskets and internal leaks, its full-bellows diaphragm and other features, is giving long years of uninterrupted service.

For consistent trouble-free metering, look to **American** simplicity of design.

Descriptive catalogs are available on request.

AMERICAN
METER COMPANY
INCORPORATED (ESTABLISHED 1836)
METRIC METAL WORKS • ERIE, PA.

2186



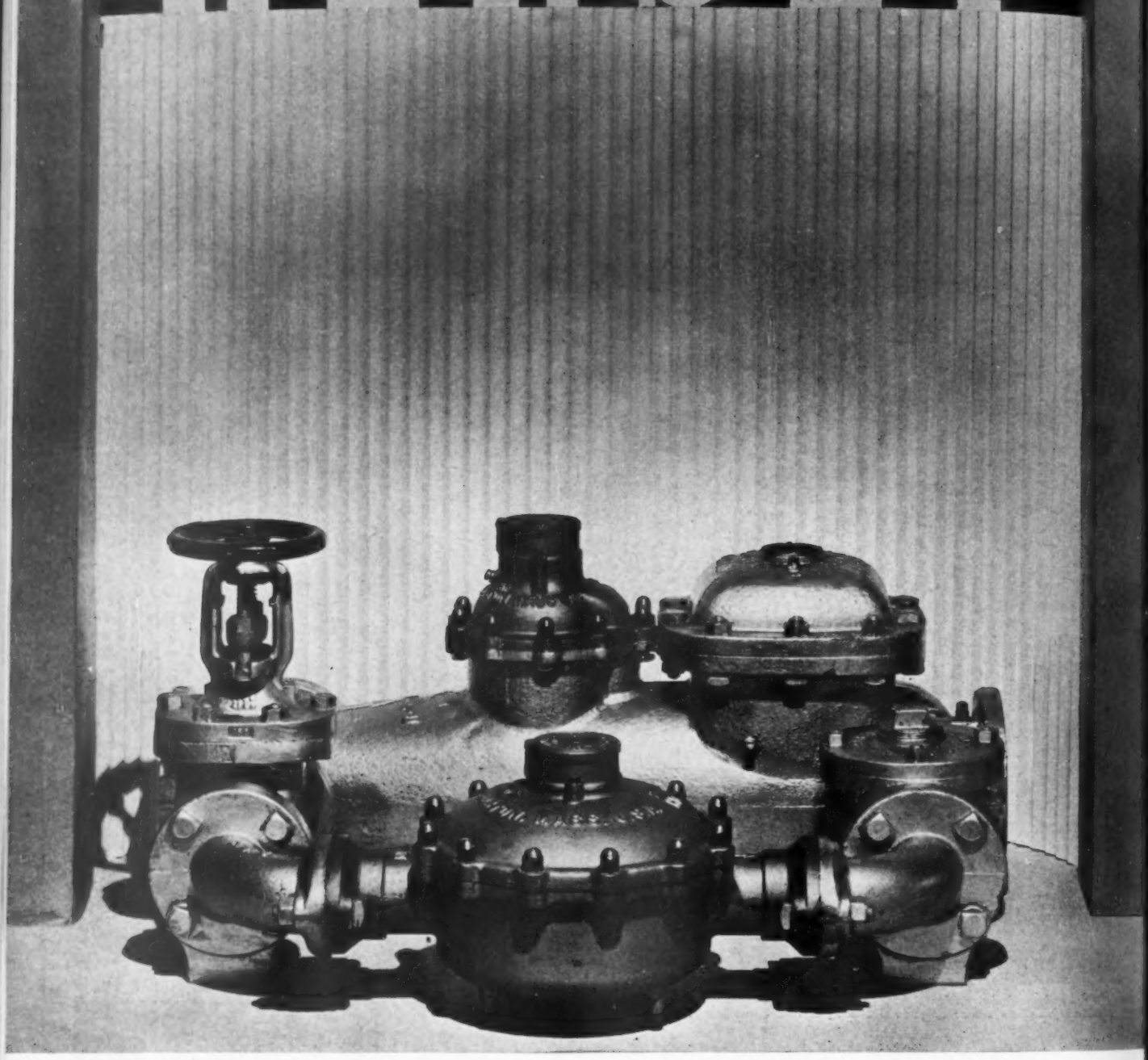
72-inch flanged Y-Branch weighing 17 tons being secured to special underslung car for rail shipment to a War Project. Drawn by Rico Lebrun for U. S. Pipe & Foundry Co.

Our facilities for producing fittings and castings in large sizes are adequate for any requirement. An experience of more than forty years in designing pipe and fittings, as well as special castings, for out-of-the-ordinary requirements, is at your service. Inquiries receive prompt attention and entail no obligation.

U.S.
cast iron
PIPE

U. S. PIPE & FOUNDRY CO.
General Offices: Burlington, N. J.
Plants and Sales Offices throughout the U. S. A.

HERSEY



THE HERSEY DETECTOR METER

has never been equalled for its accuracy in metering fire services. It always delivers the full capacity of the supply pipe without endangering the pressure. Accepted by Water Works officials. Approved by the National Board of Fire Underwriters.

HERSEY MANUFACTURING COMPANY
SOUTH BOSTON, MASS.

BRANCH OFFICES:
NEW YORK — PORTLAND, ORE. — PHILADELPHIA — ATLANTA — DALLAS — CHICAGO — SAN FRANCISCO — LOS ANGELES

RIGHT DRESS ...FOR TOMORROW

When Johnny and his buddies come marching home, it's up to every community to have plenty of big jobs for their own men to do. One sound way to insure the future of your local citizens is to plan important public works projects NOW—projects which will give your men the steady employment they'll need during the period of "war-to-peace conversion."

The manufacture and installation of Lock Joint Concrete Pipe for your water supply lines, sewerage and drainage programs provide one of the best methods for putting your local men to work quickly—right in your own home town. Past experiences have proven that by erecting temporary local plants as much as 90% of your local labor can be used in building these dependable and economical pipelines. In addition, the Lock Joint Pipe Company buys the bulk of supplies and materials from your own merchants—and thus, most of the cost of the project remains in your community.

Whether your project is large or small, for the present or the future, your 'phone call, telegram, cable or letter to any of our offices will bring a prompt reply.

LOCK JOINT
Reinforced Concrete
PRESSURE PIPE

LOCK JOINT PIPE COMPANY
Established 1905
AMPERE, NEW JERSEY

Denver, Colo. • Chicago, Ill. • Kenilworth, N. J. • Kansas City, Mo. • Rock Island, Ill.
Joplin, Mo. • Valley Park, Mo. • Cleveland, Ohio • Hartford, Conn. • Navarre, Ohio

SCOPE OF SERVICES *Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply Mains as well as Concrete Pipe of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous lines.*

CUE FOR YOU FROM THE BIGGEST JOBS

Why WORTHINGTON-GAMON *Water Meters Get the Call on the Largest Contracts*

Here are the reasons why Worthington-Gamon Water Meters have been specified on the largest contracts ever awarded in the United States.

1. Long-life performance, result of the longest experience of any water meter manufacturer.
2. Low-cost maintenance, result of famous Worthington manufacturing controls, established by this leader among firms supplying many types of equipment to municipalities.
3. Ability to measure minims of water, result of constantly improved Worthington-Gamon design.

In addition to these essentials, Worthington-Gamon offers the most extensive service facilities of any meter company . . . 24 district offices in 24 leading cities plus Worthington Research Laboratories including a staff of highly skilled water meter technicians.

When you specify Worthington-Gamon Water Meters, you too will benefit by the reasons that get first call for Worthington-Gamon Meters on the largest contracts.

Subsidiary of

WORTHINGTON PUMP & MACHINERY CORPORATION

Power Plant Equipment • Turbines & Turbo-Generator Sets • Condensers, Heaters, Ejectors • Water Purification Equipment • Diesel & Gas Engines • Pumps, Stationary and Portable Compressors • Air-Conditioning & Refrigerating Equipment • Power Transmission Equipment • Construction Machinery, Equipment for Mines • Locomotive Feedwater Heaters • Welding Positioning Equipment • Liquid Meters

WORTHINGTON-GAMON METER COMPANY
282-296 South Street, Newark, New Jersey

The Meter Specified in the Largest Contracts Ever Awarded in the U. S.

"Watchdog" models . . . made in standard capacities from 20 GPM up; frost proof or split case in household sizes. All parts interchangeable with your present meters of our manufacture. Write for Bulletin.

HOODCHLOR — "Gunga Din" of the U. S. A.

View of water point on New Georgia Island, during actual invasion period. At left: Lining up for safe drinking water purified with HOODCHLOR. Official photos courtesy of U. S. Army Engineers.

HOODCHLOR contains over 70% available chlorine in dustless, granular form, and retains its strength for a year or more. In addition to its use for potable water treatment by municipal and private water works, it is valuable in sewage disposal treatment, in swimming pool and hospital sanitation and for disaster relief.

HOODCHLOR is available in limited quantities for civilian use, subject to prior demand by the Armed Forces.

Safe drinking water is assured our soldiers, sailors and marines at the front through the use of HOODCHLOR High Test Hypochlorite, —the "GUNGA DIN" of the U. S. A. By its magic, water such as Gunga Din brought to Kipling's soldiers is made pure and palatable.

HOODCHLOR is packed:

12—3¾ lb. cans to the case
9—5 lb. cans to the case
60—6 oz. cans to the case
100 lb. drums

Send for folders giving full details and directions.

HOOD CHEMICAL CO., Inc.

Executive Offices: 450 West 31st Street, New York, N. Y.
Factory: Akron, Ohio

HOODCHLOR HIGH TEST CALCIUM HYPOCHLORITE · CAUSTIC SODA
BICARBONATE OF SODA · SODA ASH · CHLORIDE OF LIME

VICTORY FIRST..

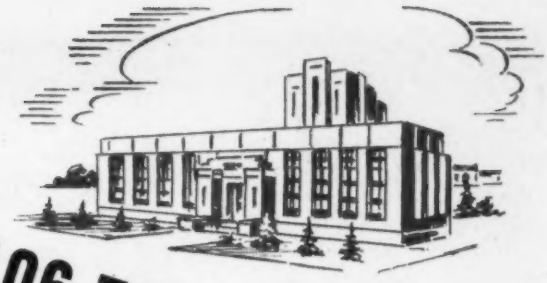
We Americans, no matter in what walk of life, realize that armament work must come first. IT MUST TAKE PRECEDENCE OVER EVERYTHING ELSE IF FOR NO OTHER REASON THAN THIS—THAT WE MAY PRESERVE FOR THE FUTURE THOSE VERY BUSINESSES OF WHICH WE ARE NOW TEMPORARILY DEPRIVED. If we fail, everything is lost—our businesses, our freedoms and our democratic way of life.

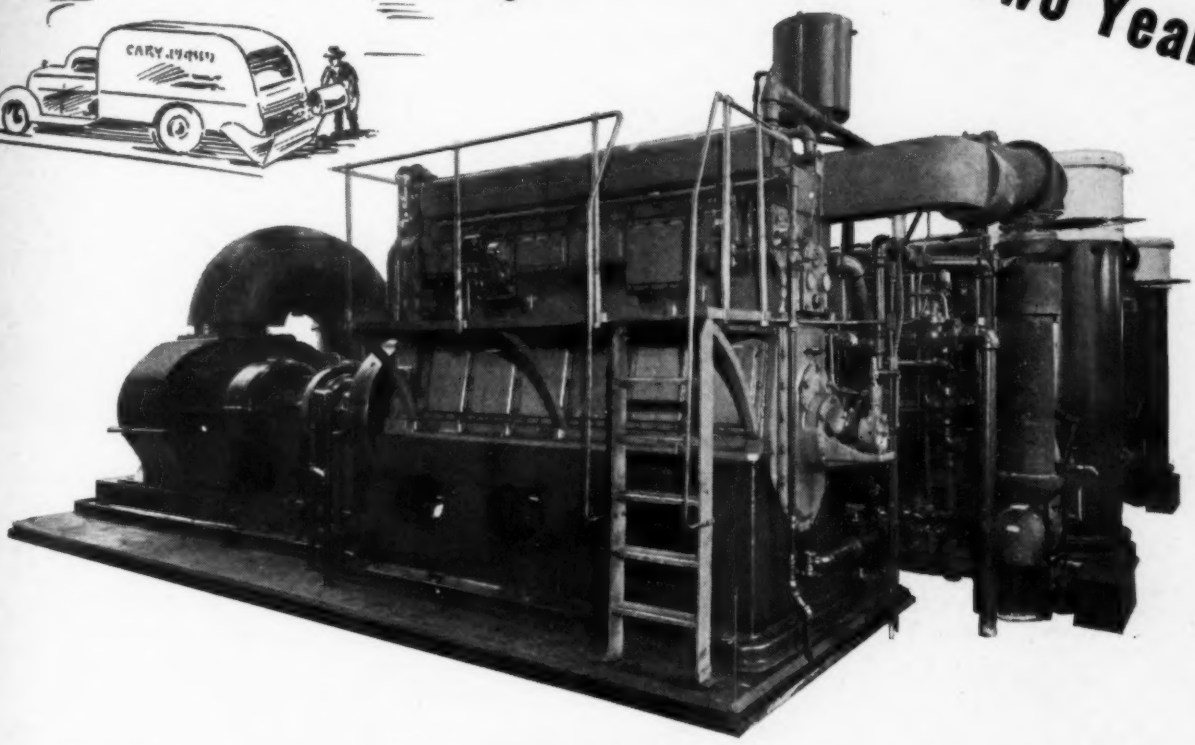
In a happier yesteryear STREAMLINE copper pipe and bronze solder type fittings were installed in thousands of buildings where a permanently reliable plumbing or heating system was essential. They were used for air conditioning, for water service piping from main to building—for sewage disposal systems and a thousand other uses where dependability and long service life were of prime importance. They were, and still are, universally considered the finest materials that money can buy. TODAY MODERN EQUIPMENT AND MASS PRODUCTION HASTEN STREAMLINE FITTINGS TO OUR ARMED FORCES FOR INSTALLATION IN TANKS AND FIGHTING SHIPS OF ALL KINDS.

When the post-war period dawns, an improved and extended line of STREAMLINE products will have their full share in the rebirth of America, and the world, in the building of better homes for its people.

MUELLER
BRASS CO.
PORT HURON, MICH.

GARY, INDIANA saves $24,106.78 in Two Years with Two Cooper-Bessemer Sewage Gas Engines





GARY, INDIANA, is another example of the outstanding savings possible with Cooper-Bessemer sewage gas engines.

For forty years this big steel and industrial center, south of Chicago, poured raw sewage into the little Calumet River, thence into Lake Michigan. In 1940, after twelve years of planning, they built an activated sludge plant for sewage and garbage disposal. The new plant started operation for sewage disposal in early 1942. Serving a population of over 100,000, the daily raw sewage input averages about 21 M.G.

Two 300 h.p. Cooper-Bessemer sewage gas engines drive 7,000 c.f.m. blowers for aeration. In 1942 and 1943 the value of the sludge gas used to power these engines, figured at city gas rates, was $24,106.78.

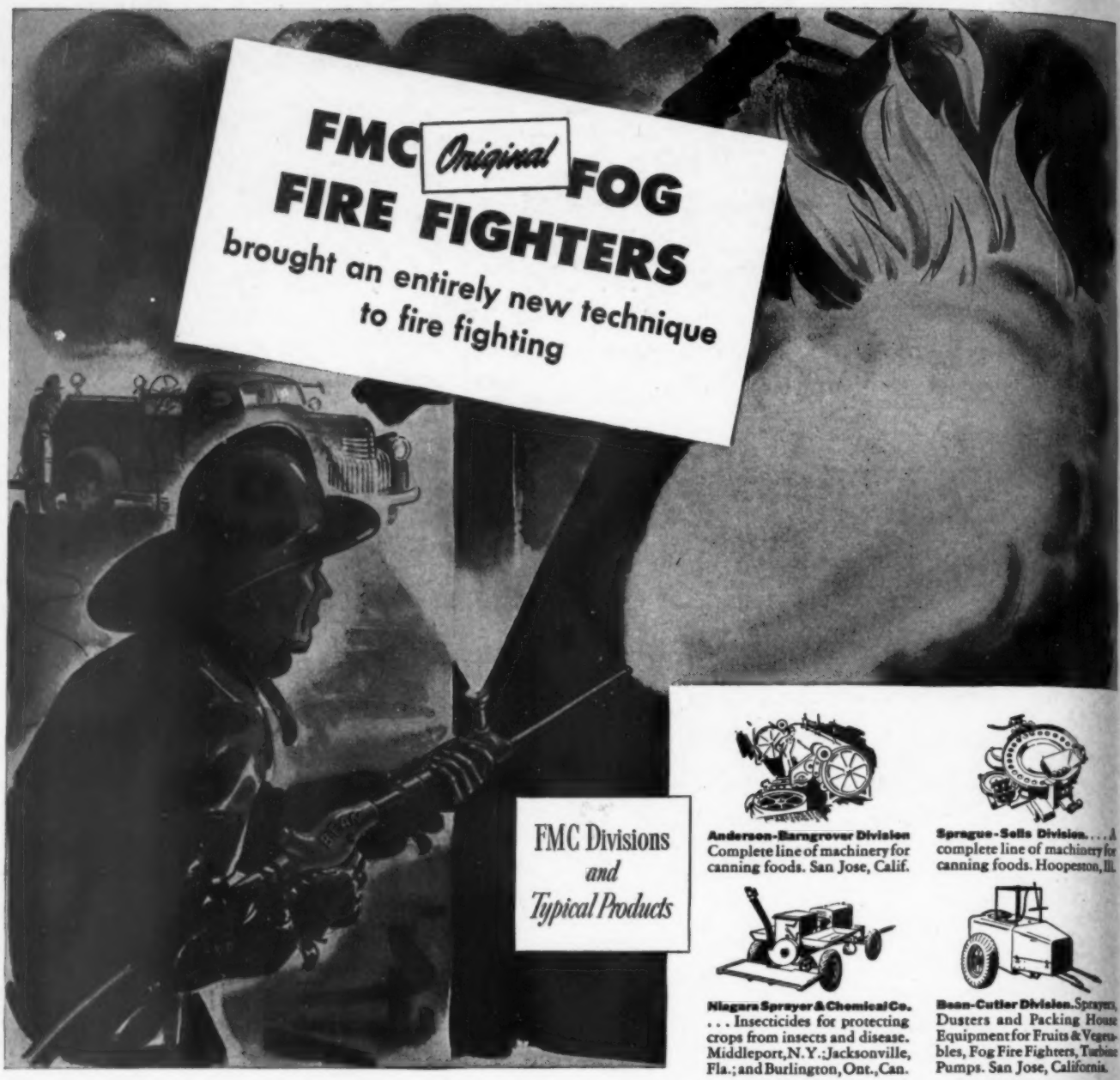
This fuel saving, representing a substantial portion of the cost of the engines, will soon pay for the equipment and will also contribute materially to reduced operating expenses for many years to come.

More and more American cities are taking advantage of the wasted power source within their sewers. More and more are installing Cooper-Bessemer sewage gas engines for long, reliable, trouble-free service. For complete details write for our free Bulletins.

THE Cooper-Bessemer CORPORATION

Mt. Vernon, Ohio • Grove City, Pa.

New York, Washington, Houston, Dallas, Tulsa, Shreveport, Los Angeles, St. Louis, Seattle



FMC *Original* FOG FIRE FIGHTERS

brought an entirely new technique to fire fighting

FMC Divisions *and Typical Products*

THE FMC *Original* Fog Fire Fighter, originated and developed by Food Machinery Corporation, produces a dense fog which extinguishes the hottest fires as if by magic! This *different* fire fighting machine, delivering 600 pounds pressure at the nozzle, is a self-contained unit one man can operate single-handed! • The remarkable engineering skill and manufacturing resourcefulness that builds these Fire Fighters also created and manufactures FMC "Water Buffalo" amphibious tanks—weapons now helping the Army, the Navy and Marines smash the Japs on land and sea.

At right are shown a few representative products of Food Machinery Corporation, world's leading makers of food processing and packing equipment.

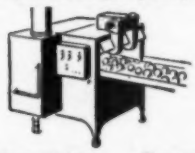
LAKELAND AND RIVERSIDE

Anderson-Barngrover Division Complete line of machinery for canning foods. San Jose, Calif.

Sprague-Sells Division. . . . A complete line of machinery for canning foods. Hoopeston, Ill.

Niagara Sprayer & Chemical Co. . . . Insecticides for protecting crops from insects and disease. Middleport, N.Y.; Jacksonville, Fla.; and Burlington, Ont., Can.

Bean-Cutler Division. Sprayers, Dusters and Packing House Equipment for Fruits & Vegetables, Fog Fire Fighters, Turbine Pumps. San Jose, California.



Texas Division . . . Protective Processes, Canning Machinery, Fruit and Vegetable Packing Equipment. Harlingen, Texas.

Florida Division . . . Citrus and Vegetable Packing Equipment, and Food Protective Processes. Dunedin and Lakeland, Florida.

John Bean Mfg. Co. Fog Fire Fighters, Bean Royal Spray Pumps, Automotive Service Station Equipment. Lansing, Mich.

Riverside Division. Citrus Packing Equipment, Automatic Box Making and Lidding Machinery, Fruit and Vegetable Protective Processes. Riverside, Calif.

PEERLESS PUMP DIVISION. Deep well turbines, hi-lifts and pumps handling water for every purpose. Los Angeles and Fresno, California; and Canton, Ohio.

FOOD MACHINERY CORPORATION

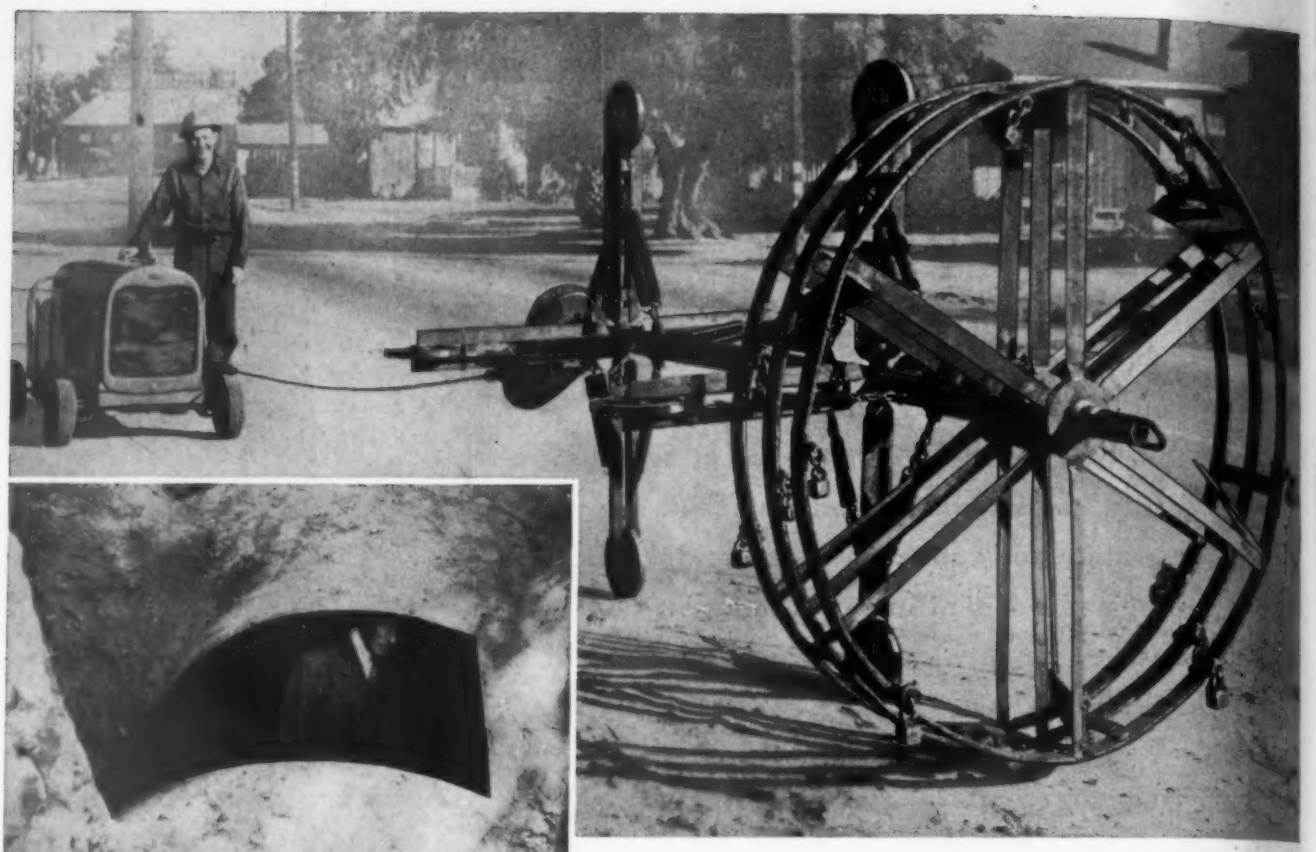
EXECUTIVE OFFICES: SAN JOSE, CALIFORNIA

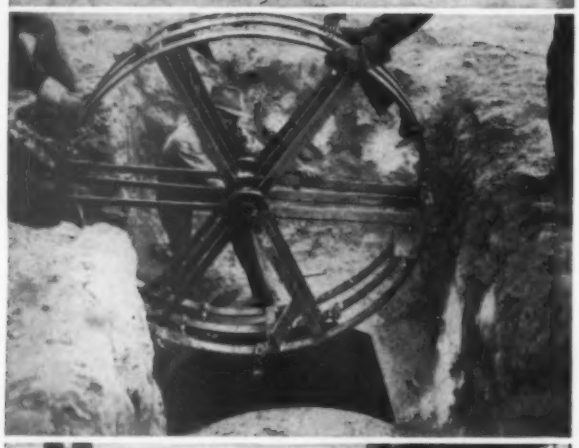
YOUR ATTENTION, PLEASE!

One of these days, we hope soon, millions of demobilized service men will be looking to you for jobs. They will expect you to have this work ready. With the great reservoir of badly needed water works and sewage works maintenance, rehabilitation and expansion that has been piling up there can be no excuse for not having everything in BLUEPRINT FORM—READY FOR CONTRACT.

Once again, we join the Committee on Water and Sewage Works Development in urging you, for the welfare of our service men, your community, and the Nation at large, to determine tomorrow's needs today and BLUEPRINT NOW!

Made by R.D. WOOD Company





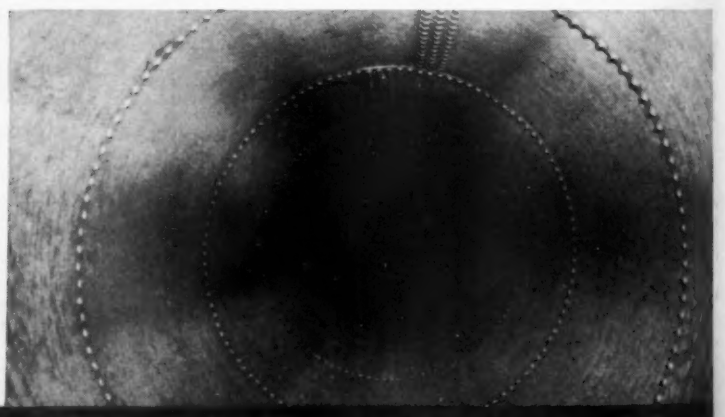
72-Inch Trunk Line Cleaned by FLEXIBLE

The 72-inch propeller-type chain head auger illustrated above was especially built for cleaning a 72-inch riveted steel pipe serving as a trunk line for the Los Angeles water system.

Illustrations at the left show the opening cut into the pipe, inserting the auger and entering the guide.

Below is shown the inside of the line after it was cleaned ready for placing the cement lining. Cement lining was done by American Pipe and Construction Co.

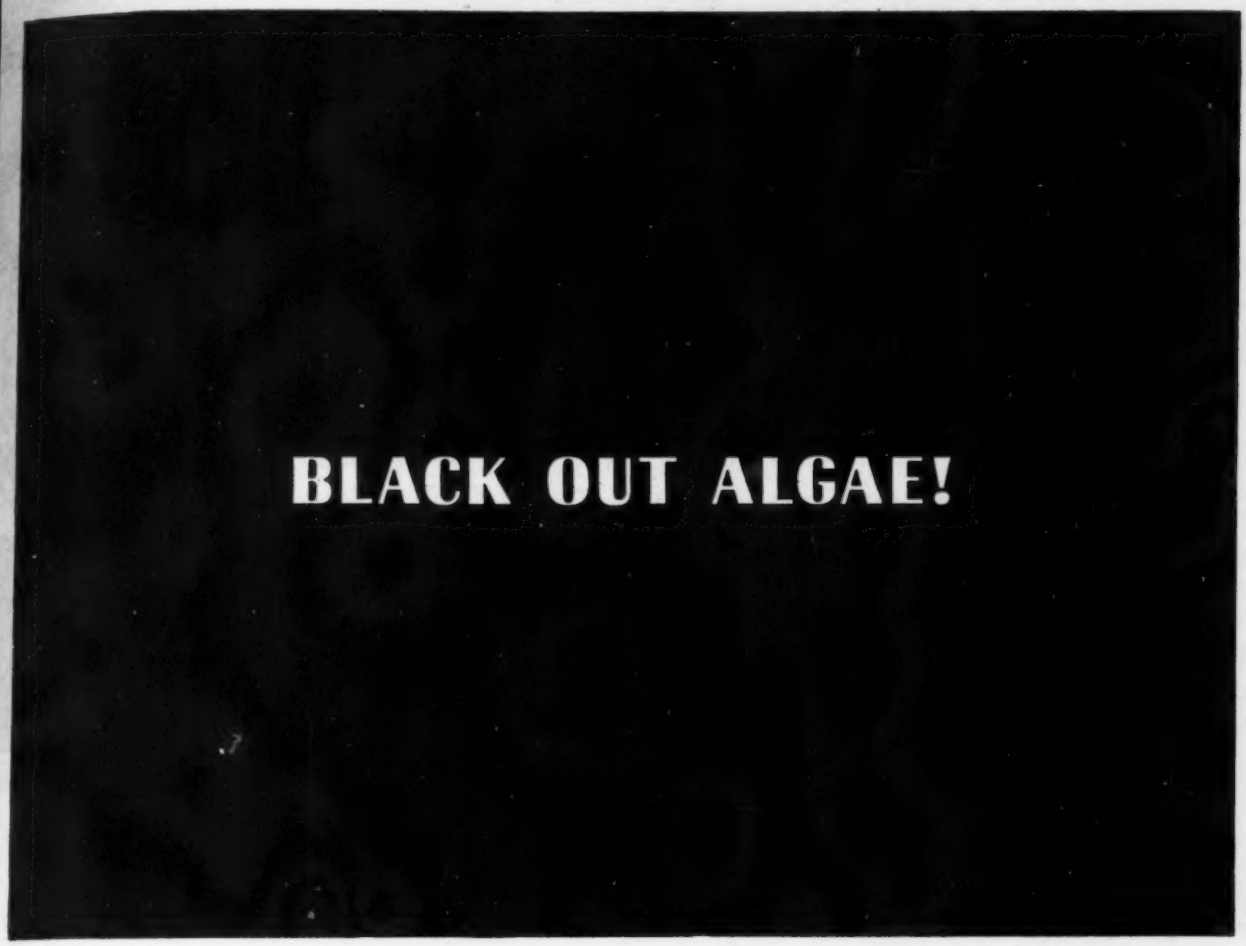
FLEXIBLE WILL CLEAN ANY PIPE—2-inch to 72-inch



FLEXIBLE UNDERGROUND PIPE-CLEANING CO.

9059 Venice Boulevard, Los Angeles 34, Calif.

401 BROADWAY, NEW YORK 13 • 1624 HARMON PLACE, MINNEAPOLIS 3 • PICKWICK BLDG., KANSAS CITY 6
3727 NORTH SAWYER STREET, CHICAGO 18, ILLINOIS • 41 GREENWAY STREET, HAMDEN, CONNECTICUT
BOX 694, PITTSBURGH, PENNSYLVANIA • BOX 694, GULFPORT, MISSISSIPPI BOX 165, ATLANTA, GEORGIA



Black out Algae with NUCHAR Activated Carbon

Here's a proven method of controlling the growth of algae in sedimentation basins and its resultant obnoxious tastes and odors. The application of Aqua Nuchar Activated Carbon in the mixing basin prevents penetration of the sunlight necessary for algae growth. The ability of Aqua Nuchar to remain in suspension for a long period of time stops normal propagation and growth of algae since the sun's rays cannot penetrate to any great depth.

Many plant operators have adopted the use of Aqua Nuchar Activated Carbon to control algae. We will gladly send you a treatise "Blacking Out Algae" on request. Write or wire our nearest office today.

BLUEPRINT NOW!

But above all, remember there is a war yet to be won. Maintain equipment to assure operation at 100% efficiency.

INDUSTRIAL CHEMICAL SALES

DIVISION WEST VIRGINIA PULP & PAPER COMPANY

230 PARK AVENUE, NEW YORK 17, N.Y. · 35 E. WACKER DRIVE, CHICAGO 1, ILLINOIS · 748 PUBLIC LEDGER BLDG., PHILADELPHIA 6, PA. · 844 LEADER BLDG., CLEVELAND 14, OHIO

★ ★ To the Wartime Conference of the

WELCOME TO

The Home of

. . . Working for Victory

The Badger Meter Manufacturing Company was founded thirty-nine years ago. From the beginning our engineers and craftsmen have worked together in untiring research and development, resolved to make the best precision products. This determination and priceless experience qualified us for precision war production.

Peacetime skills have been applied to war production. Eager to give all-out aid to the Nation's war effort, determined Badger men and women tackled the complex conversion and production problems with heart and soul. Exacting engineering tasks and ever-increasing war production schedules assigned to us were faithfully executed with enthusiam and loyalty.

BADGER METER BOOTH at the MILWAUKEE AUDITORIUM

American Waterworks Association ★ ★

MILWAUKEE

Badger Water Meters

. . . Planning for Peace

Fortified with the additional knowledge and experience gained in war-time pursuits, after victory we will resume leadership in pioneering new developments in our field of endeavor.

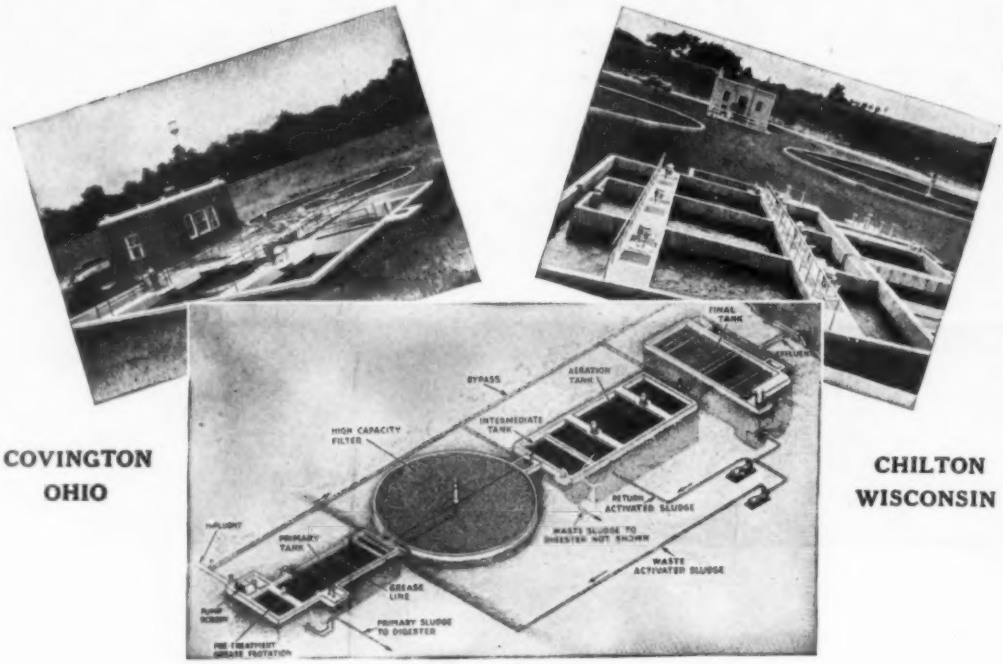
☆ ☆ ☆

We extend to you a hearty, sincere welcome to Milwaukee . . . our home city . . . that is world-famed for its hospitality. Your Badger service engineer will be at our booth in the Milwaukee Auditorium to greet you and extend every courtesy.

BADGER METER MANUFACTURING COMPANY
MILWAUKEE 2, WISCONSIN

American Bio-Actuation

WASTE TREATMENT



COVINGTON
OHIO

CHILTON
WISCONSIN

FLOW SHEET

Bio-Activation combines the best qualities of both the trickling filter and the activated sludge process to produce a completely stable, nitrified effluent, low in B. O. D. and suspended solids.

TYPICAL OPERATING RESULTS

	Domestic, Malt, Brewery and Canning Wastes	
	5 BOD	Suspended Solids
Raw Waste	342	370
Primary Effluent	235*	134
Influent to Filter	510†	.....
Filter Effluent	99	143
Intermediate Effluent	58	65
% Reduction Filter Influent through Intermediate Effluent	89.5	.....
Final Effluent	13	15
% Overall Removal	97.5	96

*High Soluble 5 BOD from malt and brewery.
†Pea waste: 600-1200 ppm. 5 BOD, added in primary effluent.

Blue Print Now! — Send for Bulletin No. 259

AMERICAN
ESTABLISHED 1866
THE AMERICAN WELL WORKS
Manufacturers of
PUMPING · SEWAGE TREATMENT · WATER PURIFICATION EQUIPMENT ·
RESEARCH · ENGINEERS · MANUFACTURERS · Factory and Laboratories · · · AURORA, ILLINOIS

8 ADVANTAGES OF VENTURI TUBES

1 LOW PRESSURE LOSS

hence lower cost of pumping than incurred by orifice plates and flow nozzles producing equivalent differentials. In gravity lines under very low heads, low loss may be of vital importance in obtaining required maximum flows.

2 INITIAL ACCURACY MAINTAINED

since the smooth, streamlined bronze or stainless steel throat resists corrosion and erosion, thus retaining its original surface and dimensions.

3 METER ACCURACY CAN BE CHECKED

The Instrument readings can be compared at any time with differential mercury column connected to the Tube at inlet and throat.

4 UNINTERRUPTED SERVICE

The flow through the Tube does not have to be shut off to adjust or repair the connected Instrument.

5 SHORT APPROACH PIPE

compared with an orifice, requires much less straight length of pipe line preceding inlet and none beyond outlet, hence installed correctly in relatively short space.

6 FAULTY INSTALLATION AVOIDED

Factory assembled, hence pressure taps, vents, throat portion, etc. correctly machined and positioned.

7 FREE PASSAGEWAY

Rapidly accelerating velocity toward and through the throat insures free passage of silt and solids, maintaining a clear interior.

8 NO MOVING OR INWARDLY PROJECTING PARTS

The interior of a Venturi Tube is entirely free from mechanical elements, plates or piezometer tubes.

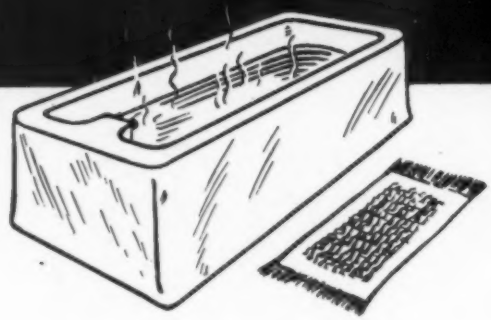
For Bulletin 143A describing the construction of Venturi Meter Tubes, address Builders-Providence, Inc., (division of Builders Iron Foundry), 9 Codding Street, Providence 1, R. I.

"BLUE PRINT NOW"

Sincerely Yours.

BUILDERS-PROVIDENCE

If 130,000,000 Americans took a Bath on the same Saturday Night!



To say the least, it would be a strain on the drain!

Seriously though, the problem of adequate pure water supply in the present, and in the future with possible population shifts and industrial readjustment, is one which concerns all of us who are associated with the water and sewage fields.

So much has been said of "Blueprint Now" that unless we are all on the alert, the facts which this slogan expresses may be lost. And if they are lost, many of us may face a hectic post war existence.

As a manufacturer whose effort is centered around the problem of sanitation, Simplex Valve and Meter Company is not interested in "force feeding" anyone into buying before he needs to buy; our interest is in extending to you the full facilities and experience of our company toward the end that your planning will be simplified and completely to your desires. Don't hesitate to get in touch with us.

Write today for further information and details of installation of Simplex "TG" Insert Venturi Tubes.

SIMPLEX VALVE & METER COMPANY
6743 UPLAND STREET, PHILADELPHIA 42, PA.

NO-OX-ID

IRON + OX = RUST

REG. TRADEMARK • AUG. 27, 1918

The ORIGINAL Rust Preventive

SETTING NEW RECORDS IN WATER WORKS AND SEWERAGE PLANTS

One of the pictures below illustrates a pressure filter tank which had been in use 50 years. The other picture is of the same tank after completely reconditioning with NO-OX-ID. This is one of 36 tanks similarly treated.

NO-OX-ID is a non-drying coating containing rust inhibitors, which not only provide the proper mechanical protection, but chemically prevent corrosion under the film, thus providing complete protection.

Wherever there is steel to protect from the corrosive attack of water vapor moisture or corrosive action of carbon dioxide along with acids set up by chemical action, NO-OX-ID will do the work. Dearborn Chemical Company, NO-OX-ID Division, 310 South Michigan Avenue, Chicago 4, Illinois.

Illustrating pressure tank prior to removing 50 year deposit of rust.

Same pressure tank after cleaning and with NO-OX-ID applied to the surface.

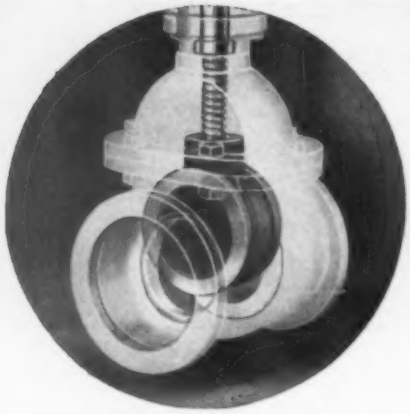
NEW 32 PAGE BOOK JUST OFF THE PRESS

Dearborn Chemical Company
Department Y
310 South Michigan Avenue
Chicago 4, Illinois

Name_____

Address_____

City_____ State_____



LUDLOW DOUBLE DISC GATE VALVES

The parallel seat, double wedge type slide gate valve, developed and perfected by Ludlow, provides a number of essential benefits. For instance:

- *Smooth, Positive Operation.* Gates positioned *directly* opposite ports before wedging, and entirely unwedged *before* being raised.
- *Positive Closure*—even after years of service in the open position; flexible-action gates *self-adjusting* to seats.
- *Self-Cleaning.* Rings cleaned *throughout entire stroke. No internal guides* to cause foul-up
- *Ready Replacement of Parts.* Simple construction with ample tolerances, permitting ready replacement of parts.

LUDLOW FIRE HYDRANTS

Distinctive List 90. Design now serving in thousands of cities and towns. *No Ludlow Fire Hydrant has ever failed in line of duty!* Employs famous Slide Gate Feature and offers the following advantages:

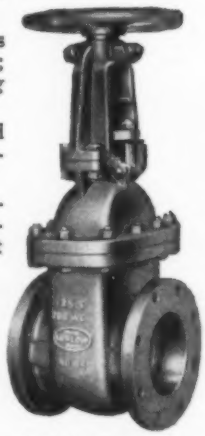
- *Quick Water* with least possible shock. Proper shut-off without water hammer.
- *Proper Drainage.* Hydrant automatically drained at *lowest* point when closed.
- *No Flooding.* Accidental breaking of the hydrant, such as might result by collision from a heavy truck, will not cause flood since the gate when closed is wedge-locked.
- *Easy Inspection and Servicing* without unscrewing anything below the ground level. All working parts removed as one unit by lifting stem through top of hydrant.

LUDLOW EQUIPMENT

Proved by the Past—Fit for the Future

In the last analysis, the best indication of future service in water works equipment is its past record. Through the years — changing systems, higher pressures, lower budgets, wartime emergency — Ludlow Valves, Gates and Hydrants have served efficiently and faithfully. You may continue to rely on them for constant service, low upkeep, resistance to wear and fewer replacements. You may rely, too, on Ludlow engineers to consider your problems their own, making honest recommendations and giving accurate estimates.

Write today for full information



Outside Screw and Yoke Type

Iron body, bronze mounted—tested at 350 lbs. hydrostatic pressure. List 44—sizes 2" to 12"—200 lbs. working pressure. List 66—sizes 14" to 48"—150 lbs. working pressure.

Iron body, bronze mounted—complying with latest A.W.W.A. Specifications. Tested at 300 lbs. hydrostatic pressure. Sizes 2" to 48".

A.W.W.A. Double Disc Gate Valve

Iron body, bronze mounted—low pressure valves. List 3 Valves made in sizes 3" to 48" and can be furnished with Hub, Flanged, Universal, Spigot, and Screwed Ends.

Valve shown with Hub Ends and without gearing. Also available with gearing or outside screw and yoke—and flanged ends.

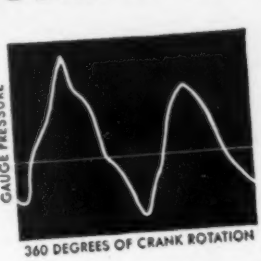
Hydraulic Cylinder, iron body, bronze mounted—manufactured in all sizes for any desired test or working pressures. Can be operated by four-way cocks or remotely controlled by solenoid valves.

Flanged End Standard Gate Valve with Cast Iron Bronze Lined Hydraulic Cylinder

The LUDLOW VALVE MFG·CO·INC· TROY·N·Y· SINCE 1866

BURGESS SNUBBER BULLETIN for Diesel Exhaust Noise Control

FIG. 1



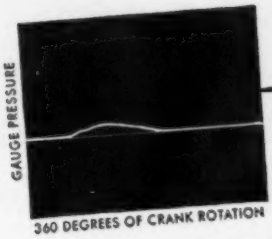


FIG. 2

WHAT SNUBBING DOES TO A DIESEL EXHAUST

The noise of a Diesel exhaust is caused in part by the sudden expansion of slugs of gas as they are exhausted from the engine under relatively high pressure. The sudden impact of a slug of gas as it is vented to the atmosphere produces a loud concussion. These unimpaired slugs, of course, pour out of the exhaust pipe in rapid succession, and the resulting noise is deafening unless properly controlled.

A further cause of Diesel noise is the oscillation of pressure waves within the exhaust pipe. The main body of gases, traveling at high velocity, leaves the exhaust pipe with a resounding crack. Most of the gases shoot out leaving a partial vacuum in the cylinder and exhaust line. Atmospheric air flowing back into the partially evacuated pipe prevents the remaining burned gases from leaving the exhaust system. An oscillation is therefore set up which causes the characteristic Diesel exhaust roar.

In two-cycle engines, an excessive amount of burned gases may be forced back into the cylinder and cause the engine to work inefficiently. Frequently a free Diesel exhaust, unless tuned with the proper length of exhaust pipe, will interfere with scavenging. Fig. 1 shows a pressure curve of a free (unsnubbed) Diesel engine exhaust. Uncontrolled, there are wide variations of pressure. The resulting oscillations of pressure (shown by the jagged curve) create exhaust noises which are extremely disturbing.

The Burgess snubbing principle goes to the source of exhaust noise by snubbing the slugs of exhaust gases before any noise can occur. This is accomplished by spreading out the slugs and dissipating their kinetic energy before they reach the atmosphere. The slug enters the first section of the snubber—expands and loses much of its energy. Each of the remaining two snubbing sections dissipates the slugs still further so that the exhaust gases enter the atmosphere in a relatively steady flow. In addition, there can be no harmful reflected pressure surges to oscillate in the exhaust pipe to create additional noise and interfere with engine efficiency. Fig. 2 shows a pressure curve of the exhaust of the same Diesel engine when a Burgess Snubber is used. The exhaust slugs are dissipated, hence, there are no resultant noise-making surges.

DISPOSAL PLANT OPERATES DIESELS ON SEWAGE GAS

The Nine Springs Sewage Disposal Plant, Madison, Wisconsin, has been in operation for a number of years.

The power plant consists of two Cooper-Bessemer Diesel engines, one a 320 hp. 6-cylinder, and the other a 230 hp. 8-cylinder unit. Economies of operation are obtained because both engines operate on sewage gas. A waste heat boiler located in the exhaust system is so arranged that heat may be obtained for heating the building or to provide hot water for the water system in the plant.

Each engine exhaust is equipped with a Burgess Snubber which snubs the explosive, fast-flowing exhaust gases before they reach the air. Therefore, the engine exhausts are vented, without noise, in a quiet, steady flow.

Many municipal waterworks and sewage disposal plants, operating on Diesel power, find that the Burgess Snubber not only eliminates objectionable exhaust noises but also increases engine efficiency. A Burgess Snubber prevents engine "choke" or oscillation in the exhaust pipe by snubbing the excessive back surges in the exhaust system.

HELPFUL HINTS

SAI Intake Snubber

O-F Air Cleaner

DON'T OVERLOOK AN INTAKE SNUBBER AND AIR CLEANER

A Diesel engine must breathe freely. Any "choking" of the air intake impairs engine efficiency. A Burgess Snubber smooths the flow of intake air without "choking" the intake pipe.

An intake snubber should be used to smooth the flow of intake air and to level off high peak air intake velocities of pump scavenged 2-cycle engines. Otherwise oil pull-over may take place, creating additional filter maintenance problems.

Air filters require frequent servicing—at least twice a week. Care should be taken to see that the air filter is placed where servicing can be easily done.

Published by **BURGESS-MANNING COMPANY** Chicago, Illinois

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When Blueprinting for Tomorrow—

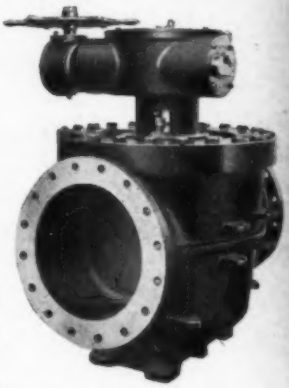
particularly, the handling and controlling of Water and Sewage—

plan to use SMITH AXIAL-FLOW PUMPS *and* FREE FLOW ROTOVALVES

The Automatically Adjustable Blade Impeller Axial Flow PUMP

DESIGNED to meet water pumping and controlling needs. Adopted by leading engineers and officials in modern waterworks, sanitation plants, and flood control systems. Available with either fixed or automatically adjustable blades—which vary the discharge by changing their pitch while the pump is in operation—particularly, advantageous for low varying heads and high volume requirements. Write for Bulletin 142.

The Free Flow ROTOVALVE

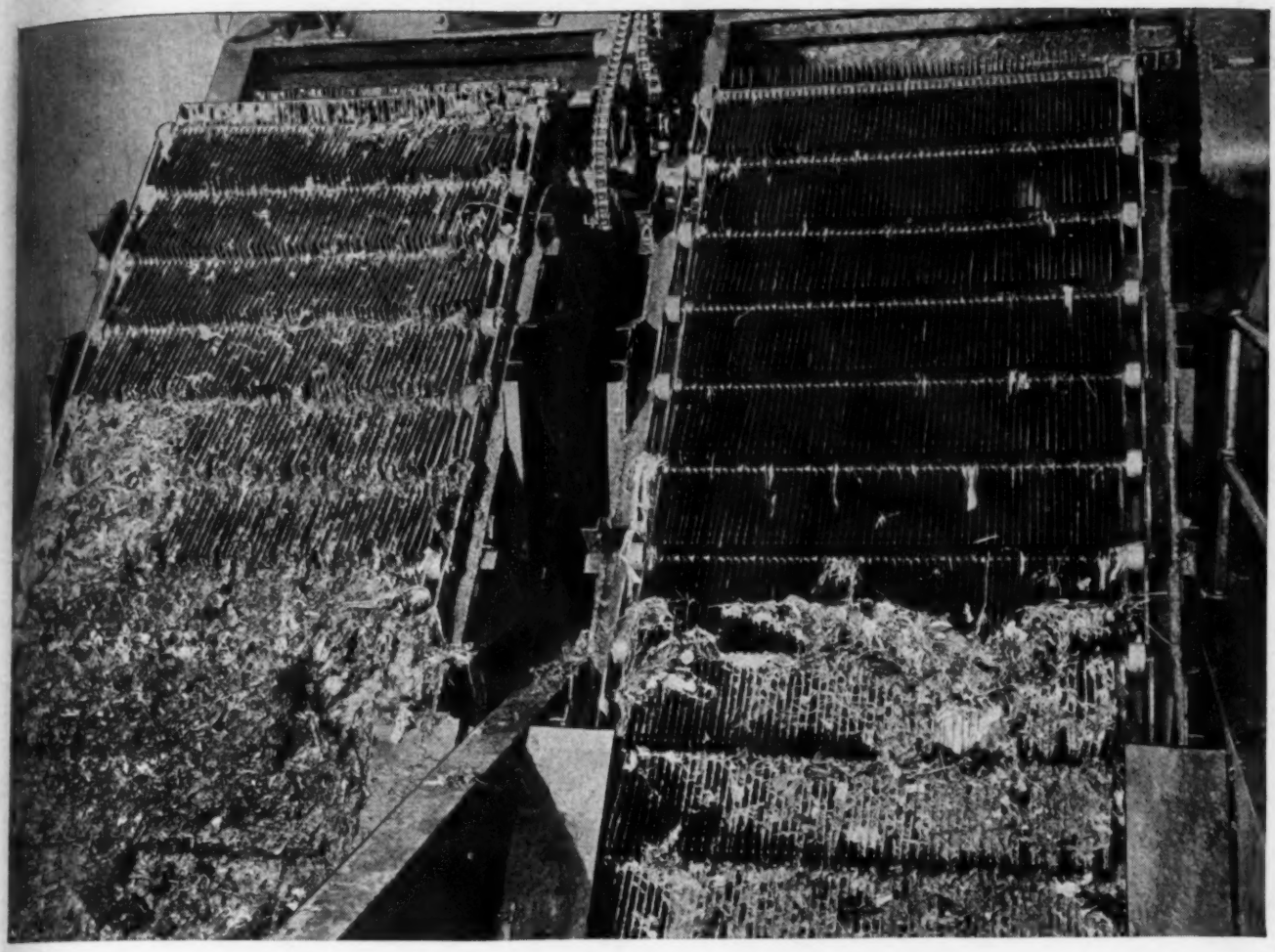


A CONE-type plug valve with full circular opening, thus assuring free flow and losses no greater than in a pipe of equal length and diameter, and with operating mechanism that will lift, rotate and reseat the valve plug. Adaptable for hydraulic, motor, manual, or pneumatic operation. A one-type, multiple-purpose valve for all water and sewage uses obtainable by merely changing the control mechanism, or the actuating means. Full details in Bulletin 140. Send for it!

Enjoy the full benefits of efficiency in operation tomorrow by planning wisely, today. Profit by our 69 Years of Experience in Hydraulics! Put your problems up to us!

S. MORGAN SMITH Co.

YORK, PENNA. U.S.A.



EVERDUR BLADES *"in perfect condition"* AFTER TWELVE YEARS OF HARD SERVICE

The Everdur* blades on this Laughlin Automatic Traveling Type Screen installed in the Dearborn, Michigan, Sewage Treatment Works, have taken twelve years of punishing service, yet are still sound. This is even more remarkable in view of the fact that the Dearborn Plant mixes industrial waste, sanitary sewage and storm water, subjecting the Everdur to unusual amounts of grit and corrosive waste.

M. A. Groen, Chief Operator at the plant had these conditions in mind when he enthusiastically wrote:

> "Not one out of the 5336 Everdur blades needed replacing due to abrasive action...or corrosion. "The strength of these blades is also remarkable, for bent blades can be straightened repeatedly without breaking."

Twelve years of trouble-free service, and ready for more in years to come... Everdur is proven metal where strength and resistance to a wide range of corrosive conditions are essential. 44174

*Reg. U. S. Pat. Off.

EVERDUR METAL

is being used for Coarse and Fine Screens, Swing Gates, Built-up Sluice Gates, Coarse Bar Rack Aprons, Effluent Weirs and Scum Weirs, Structural Scum Baffle Brackets, Troughs, Screen Hoppers, Orifices, Baskets, Anchors, Ladders, Float Gage Chains, Valve Springs, Manhole Steps, Guides, Walkways, Bars and Plates, Bolts and Nuts.

ANACONDA from mine to consumer

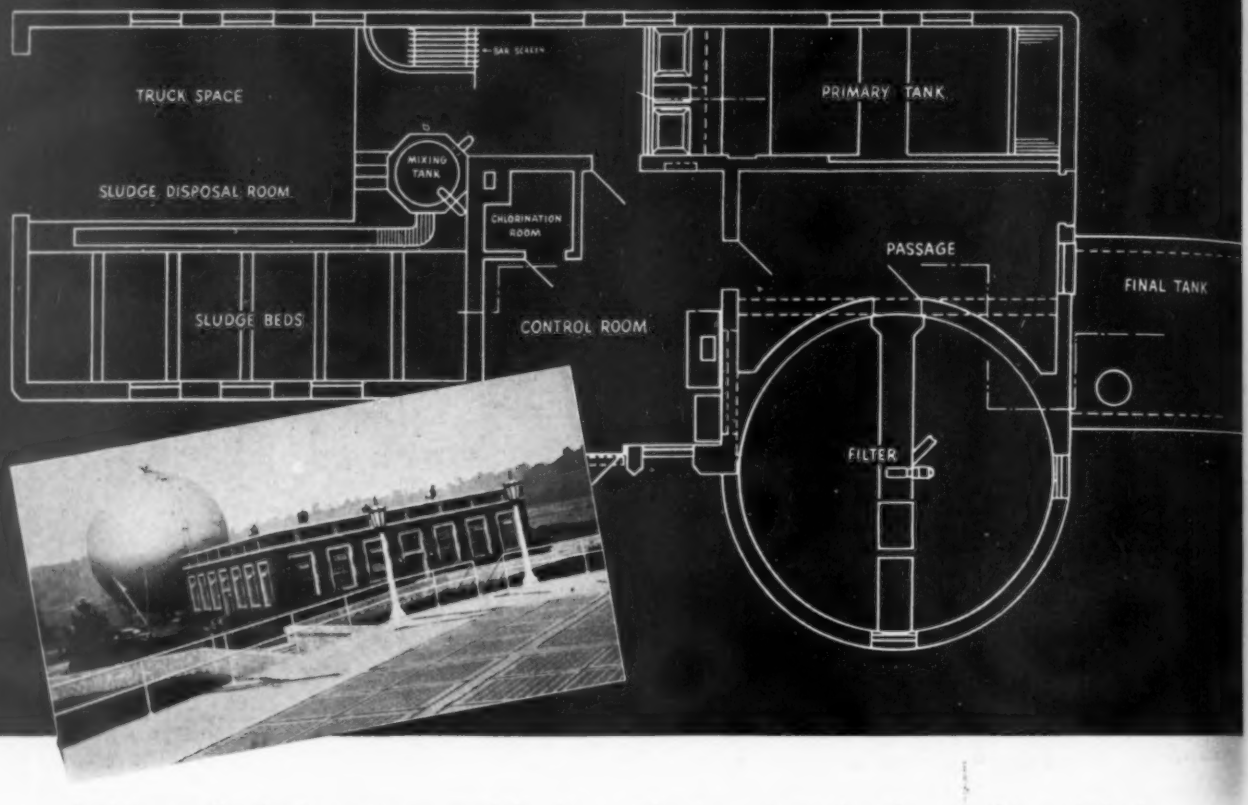
Everdur Copper-Silicon Alloy

THE AMERICAN BRASS COMPANY—General Offices: Waterbury 88, Connecticut

Subsidiary of Anaconda Copper Mining Company • In Canada: ANACONDA AMERICAN BRASS LTD., *New Toronto, Ontario*

Before you put that plant on paper

weigh the advantages of aluminum



Architecturally, the fine appearance of aluminum construction gives a community added reason for being proud of its sewage treatment plant. Makes them want it kept up well. There's less kick on plant maintenance costs.

From an operating standpoint, this construction is easier to maintain. Aluminum is naturally resistant to corrosion; needs little attention to keep it good as new. And, where conditions are unusually severe, it can be given protective coatings.

Wartime performance records show that aluminum is coming through this period of curtailed maintenance with flying colors.

Where can you use Alcoa Aluminum in your postwar plants? From skylights to sills, for decorative and utility purposes, architects have employed aluminum to advantage. From coarse screens on through all the plant processes, engineers have found it equally valuable. Alcoa engineers will gladly help you determine where you can use it. ALUMINUM COMPANY OF AMERICA, 1955 Gulf Building, Pittsburgh, Pennsylvania.

ALCOA ALCOA ALUMINUM REG. T.M. **ALUMINUM**

SANITATION that meets any EMERGENCY!

A WATERMAIN bursts and the threat of deadly pollution looms. But with Mathieson Sanitation HTH available, such threats do not become dangerous realities. For safe conditions are quickly restored with this highly concentrated, mobile chlorine carrier which contains over 70% available chlorine.

Municipal officials faced with overloaded facilities due to war conditions find Sanitation HTH an invaluable ally in meeting emergencies of every kind. They also find it ideal for regular treatment of smaller water supplies and sewage effluents, for sterilizing new watermains, for general sanitation around swimming pools and beaches, and for many other uses.

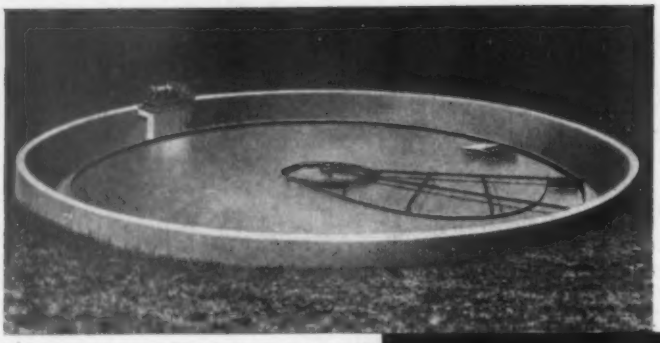
Write for a copy of valuable 80-page handbook "Hypo-Chlorination of Water". It's yours for the asking.

Packed in cases of nine 5-lb. cans and in 100-lb. drums.

Mathieson
CHEMICALS

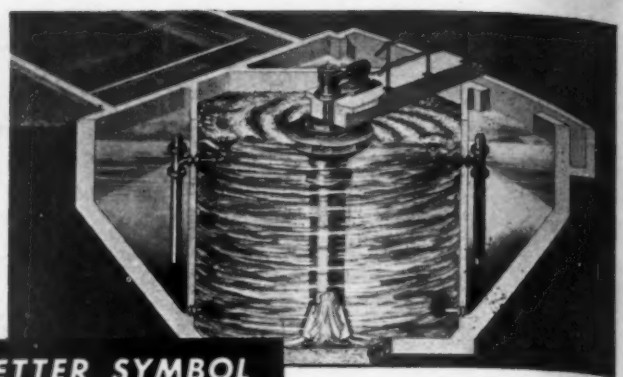
THE MATHIESON ALKALI WORKS (INC.) 60 EAST 42nd STREET, NEW YORK 17, N. Y.

SANITATION HTH..LIQUID CHLORINE..PH-PLUS..FUSED ALKALI..CAUSTIC SODA..SODA ASH..BICARBONATE OF SODA..BLEACHING POWDER
AMMONIA, ANHYDROUS & AQUA..DRY ICE..CARBONIC GAS..SYNTHETIC SALT CAKE..SODIUM CHLORITE PRODUCTS..SODIUM METHYLATE



YEOMANS "RIM-DRIVE" CLARIFIER MECHANISM

Smart in appearance, economical in service. Motor and drive unit mounted on rim of the tank. Cuts torque demand 95%. Simple, efficient, accessible. Bulletin 6710.

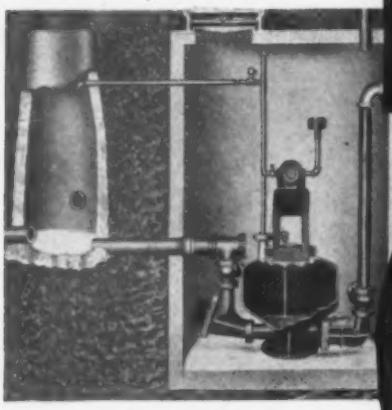


YEOMANS "AERIFIER"

Aeration and final settling in one concrete structure — simple design, with a minimum of working parts to require maintenance attention. Bulletin 6650.

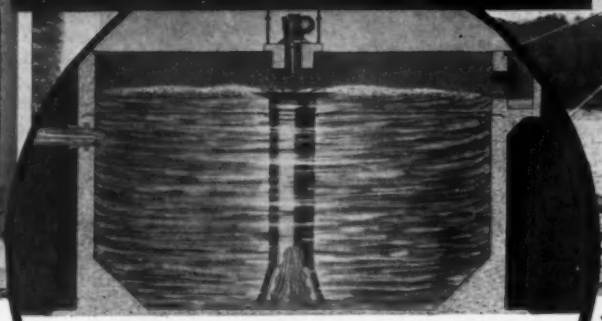
THERE'S NO BETTER SYMBOL OF RELIABLE, ECONOMICAL, TROUBLE-FREE PERFORMANCE THAN THE NAME

YEOMANS



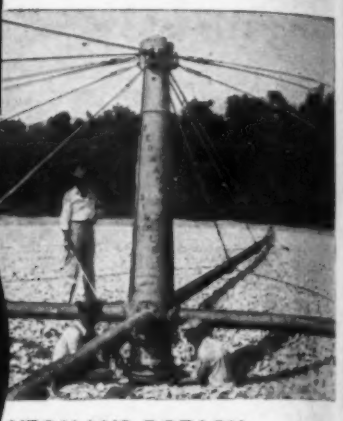
YEOMANS "SHONE" EJECTOR —STANDARD OF EFFICIENCY

Automatic, clog-proof, fool-proof, this famous unit has back of it a 75-year record for utter reliability. No screens or shredders, no wet well, the sturdy Shones are good news to maintenance men. Bulletins 4003, 4301, 4401.



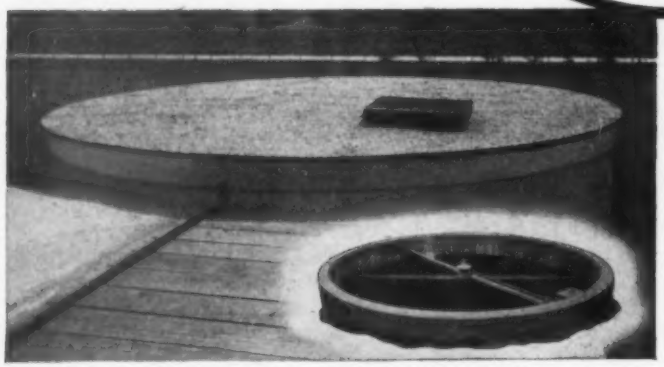
YEOMANS "SPIRALFLO" AERATOR

Low power consumption and thorough "Spiralflo" mixing combine to make an aerator that can't be excelled for high purification values and low operation and maintenance costs. The original design and still the best. Bulletin 6601.



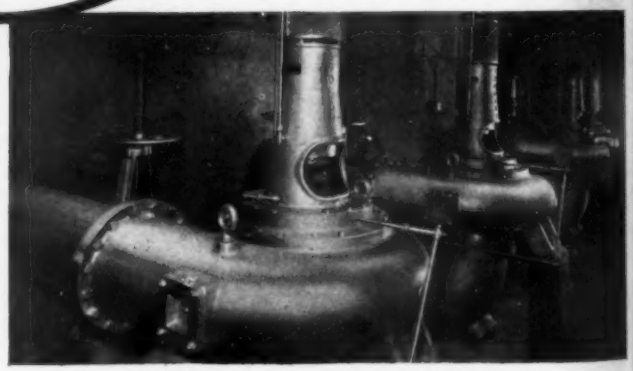
YEOMANS ROTARY DISTRIBUTOR WITH "LEVELER"

When filter beds settle and distributors fall out of plumb, the "Leveler" comes to the rescue. A simple adjustment with ordinary wrenches realigns a Yeomans distributor equipped with the "Leveler", saves big expense. Bulletin 6502.



YEOMANS "WATER-WHEEL DISTRIBUTOR

A remarkable record of unfailing performance with minimum attention proves this well-designed unit's fitness for small communities, institutions and industrial plants. Easy and inexpensive to install and maintain. Bulletin 6552



YEOMANS SEWAGE PUMPS

In every type of sewage pumping installation Yeomans centrifugal pumps are giving the sturdy, trouble-free service expected of them. A full range of sizes and types—vertical and horizontal—to meet every need. Bulletin 6201.

Yeomans Brothers Company

1423 NORTH DAYTON STREET • CHICAGO 22, ILLINOIS

Product improvement through

Bridgeport DURONZE

Is your product hampered by outmoded metals? Is a good design being nullified by mediocre materials? *Every* product should be periodically subjected to the most searching examination to determine whether the best possible engineering materials are being used.

For example, a study of Hancock's "500 Brinell" valves showed that the stems were not up to the quality of the other component parts. After changing to DURONZE, Hancock reports that the new stems have lasted *six times longer* than other materials used... and are still going strong.

Hancock selected DURONZE III, a Silicon Aluminum Bronze, which combines high strength and a low coefficient of friction with exceptional resistance to severe corrosion. Tensile strength averages between 90,000 and 100,000 lbs. per sq. in. in rod form, and approximately 80,000 to 85,000 lbs. per sq. in. as a hot forging. This alloy is also free machining. Its unusually high yield strength does not permit stretching under stresses which distort weaker materials.

Perhaps *your* product—whether a valve, an electrical connector, a machine, a pump part, gear or whatever it may be can be radically improved without any change in design, merely by specifying one of Bridgeport's modern engineering alloys for a vital or vulnerable part. If so, get in touch with one of our technical advisers. Write for 80-page DURONZE MANUAL.

Orders for DURONZE sheet, rod, wire or tubing will be accepted in accordance with existing priority regulations.

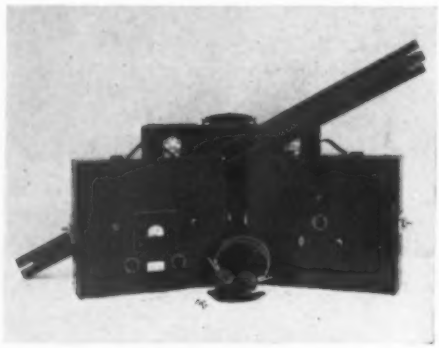
BRIDGEPORT
Duronze
A PRODUCT OF
BRIDGEPORT BRASS COMPANY
"Bridgeport" BRIDGEPORT 2, CONN. • *Established 1865*

SAVE *time, money, headaches*

by using LATEST 1944 MODEL

FISHER M-SCOPE INSTRUMENTS

The Fisher M-Scope Pipe Finder is successfully solving the varied problems involved in the development, operation and maintenance of buried pipe and cable systems.



M-SCOPE PIPE FINDER

- It locates the exact position of the object
- It traces the exact course of an underground line
- It determines the difference between a buried pipe and a single metal object
- It works positively and instantaneously
- It prevents accidental damage by diggers
- It eliminates exploratory excavations
- It saves time, labor, money

M-SCOPE ENERGIZER TYPE PIPE LOCATOR

M-SCOPE LEAK DETECTOR

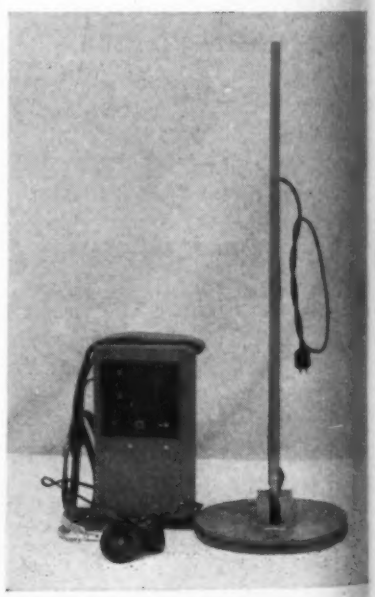
Use the Fisher M-Scope Water Leak Detector to determine the exact location of a leak. Its use will enable you to

- Locate exact position of pipe leak
- Determine where to break pavement when leak appears on the surface
- Solve the problem of "unaccounted for" water or oil
- Reduce operating expenses
- Increase net revenue
- Every leak is an unmetered user

THE FISHER M-SCOPE BOX LOCATOR

will locate valves, covered manholes, drip and service boxes, etc., as fast as you can cover the ground at walking speed. Do away with the old and slow dip-needle method. Liberal trade-in allowance on your old dip-needle.

Write to the Fisher Research Laboratory for latest 16-page booklet explaining the above methods. M-Scope Equipment is exclusively manufactured by the Fisher Research Laboratory. Please place your order now for immediate delivery from our Palo Alto, California or Chicago, Illinois warehouses.



FISHER

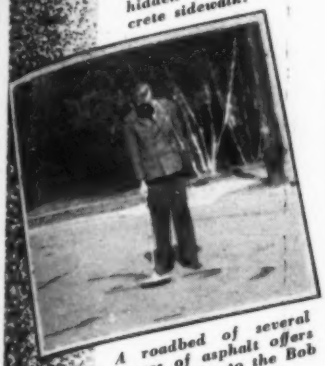
RESEARCH LABORATORY

1961-63-65 University Ave. **Palo Alto, Calif.**

Telephone PALO ALTO 24646-7-8-9

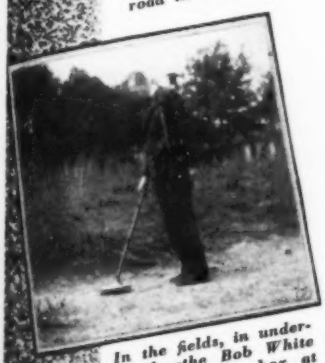
An Important Message to
WATER and SEWAGE WORKS MEN

The Bob White Goes Into Action! Locating hidden box under concrete sidewalk.



A roadbed of several layers of asphalt offers no obstacles to the Bob White.

The Bob White locates hidden box under dirt road in a jiffy.



In the fields, in underbrush—the Bob White locates hidden box at all times.

I have been engaged for thirty years in making leak surveys and solving water leak problems of all kinds for municipal, private, and industrial water works plants. Over this period of time, I have built up a reputation second to none in this field and today enjoy the esteem and confidence of everyone with whom I have come in contact while engaged in this type of engineering work.

HOW I SOLVED MY GREATEST PROBLEM

Almost immediately I found that approximately forty per cent of my time and expense was consumed in trying to find the exact location of water leaks and utility service boxes, some of which were so hidden under concrete, asphalt, and sometimes in underbrush six feet thick, that days were consumed in locating them. So I worked for years on a device that would save my own time and effort and enable me to eliminate once and for all this tedious and time-wasting, but very important, operation. After much experimenting, adjusting, and actual work in the field, I perfected for my own use the BOB WHITE ELECTRONIC BOX LOCATOR and immediately put this into use in my daily work enabling me to locate ANY and ALL hidden utility service boxes within a few minutes.

THE SUCCESS OF MY BOX LOCATOR UNKNOWINGLY EXPANDS MY BUSINESS

The first time I used my new Box Locator happened to be on a project for a municipality in the State of New Jersey. When the officials of the town and the superintendent of the waterworks plant saw my box locator in actual operation, under all kinds of weather conditions, and in every type of location, when I successfully finished my contract I was asked to sell my instrument to the town and leave it for their own use. A week later I received an inquiry from another town nearby, asking me to sell them one of my box locators. With no effort on my own part, and with none other than word-of-mouth advertising, orders for my box locators began to come to my home and office, without even a price quoted or affixed.

WHAT THE BOB WHITE BOX LOCATOR IS AND HOW IT SAVES TIME AND MONEY FOR YOU

On this page you can see my Box Locator in actual operation under several types of conditions. The Locator which I am now marketing is the exact same device which I use myself, perfected with the latest improvements, and because of this, only the best of materials and workmanship goes into it. All connections are nickel-plated, the batteries and condensers are the most expensive money can buy, and the BOB WHITE BOX LOCATOR is built to last a lifetime with reasonable care. There are no adjustments to be made for weather and temperature conditions, and it is so simple a six-year-old child can operate it successfully. It is not to be compared with any other similar device; the BOB WHITE, so far as materials, workmanship, and ability to do the job ANYWHERE, ANYTIME, with a minimum of handling, is in a class by itself.

In closing, many people have asked me why I named my Box Locator the Bob White. One of the first letters I received said, in part, "Please send me your box locator which locates hidden boxes with the sound of a Bob White." When the disc passes near or over the hidden box, the sound which it creates is the whistle of the Bob White. For this reason this customer unknowingly named my box locator for me, and it has been called the BOB WHITE BOX LOCATOR ever since.

That's the story of my Box Locator—it can be verified by past experiences, and by anyone who has bought one. Before purchasing a Box Locator, find out for yourself! Testimonials and further particulars will be sent gladly upon request.

S. F. Ferguson

S. F. FERGUSON

11 Hill Street **Newark 2, N. J.**

The Bob White goes to work in a swampy field and the hidden box is located almost immediately. Photos show types and locations of boxes which are located by Bob White. Note rule-depth of hidden box to the right.

The Important Step is *Proper Conditioning*

No matter what the source of your water supply . . . ponds, rivers, lakes, or wells—it's a raw material. It must be processed . . . properly conditioned to do its particular job. Often it has several jobs to do—boiler-feed—cooling—processing—which may mean several conditioning steps.

Graver designs, builds, and installs equipment to do each job most efficiently and economically. Whether it's a boiler-feed job requiring Hot Process softening and deaerating—a process water that requires Zeolite softening and acid treatment—iron removal—complete demineralizing—or filtration—Graver can supply the equipment that will meet your specific requirements and insure lasting satisfaction. And this complete service is backed by years of experience in solving water conditioning problems of all types in industries and municipalities all over the country.

Without cost or obligation, Graver engineers will make a study of your water conditioning needs, submit designs, provide estimates. Take advantage of this planning service now.

Graver designs, builds, and installs all types of Water Conditioning Equipment including:

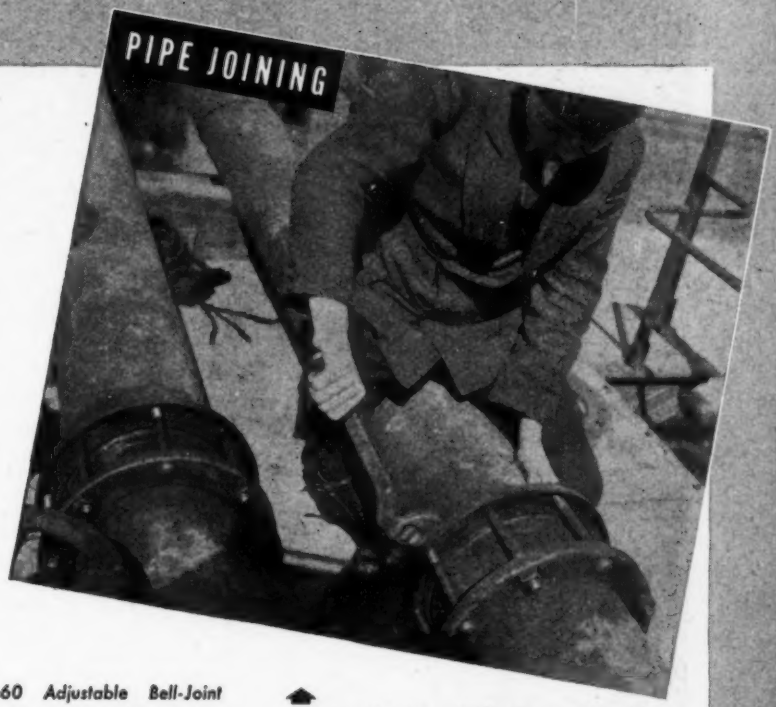
- Hot Process Water Softeners
- Zeolite Water Softeners
- Water Filters
- Iron Removal Filters
- Taste and Odor Removal Filters
- Oil Removal Filters
- Reactivators
- Deaerating Heaters
- Demineralization Equipment

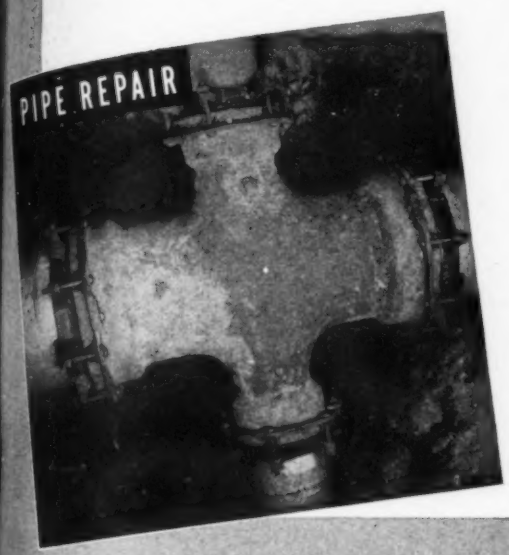
GRAVER
WATER CONDITIONING EQUIPMENT

Process Equipment Division
of
GRAVER TANK & MFG. CO., INC.
4809-43 Tod Ave., East Chicago, Ind.
NEW YORK CATASAUQUA, PA. CHICAGO TULSA

Compact, Ready-Made "DRESSERS" AVAILABLE FOR ALL KINDS OF Pipe Joining and Repair

The Dresser complete line includes accurate, efficient, ready-made Pipe Couplings, Fittings, Repair Clamps and Sleeves for practically all kinds and sizes of pipe. Over sixty years of specialization and development in this field lie behind Dresser ability to do a good job for you.





◀ *Style 60 Adjustable Bell-Joint Clamps are so designed that a very close fit may be made. They stop leaks promptly and permanently, and are often used on new lines to save cost of future repair.*

▲ *Antwerp, Belgium—1939. Dresser Couplings join pipe used to transport oil products from tankers to storage. Terrain is wet, swampy, unsettled. Customer commends Dresser facilities for realizing deflection.*

"Dressers" appear above in two specific applications. They are used extensively, however, throughout the maze of piping that serves so well the gas, water, oil, marine, mining, chemical and other fields.

Couplings consists of two resilient gaskets compressed between metal rings and against the pipe by bolts. They make strong, flexible, tight joints, night or day, in any weather. Installation is easy and fast. Pipe ends ride within the gasket seal which automatically absorbs expansion, contraction, deflection and vibration that might cause breaks in rigid connections. When you make plans for new lines or plan repairs for old ones, investigate the many advantages of compact, ready-made Dresser products. *Catalog 402 BP on request.*

LEADING DRESSER PRODUCTS

- Regular Steel Couplings
- Cast Couplings
- Long Couplings (Sleeves)
- Light Couplings
- Insulating Couplings
- Joint Locking Devices
- Mechanical Joint for CIP
- Ells, Tees, Crosses, Wyes
- Expansion Joints
- River Clamps and Sleeves
- Saddles and Nipples
- Compression Fittings for small pipe
- Repair Clamps for pipe and pipe joints
- Split Repair Sleeves
- Specials

Save Man Power with Dresser Couplings

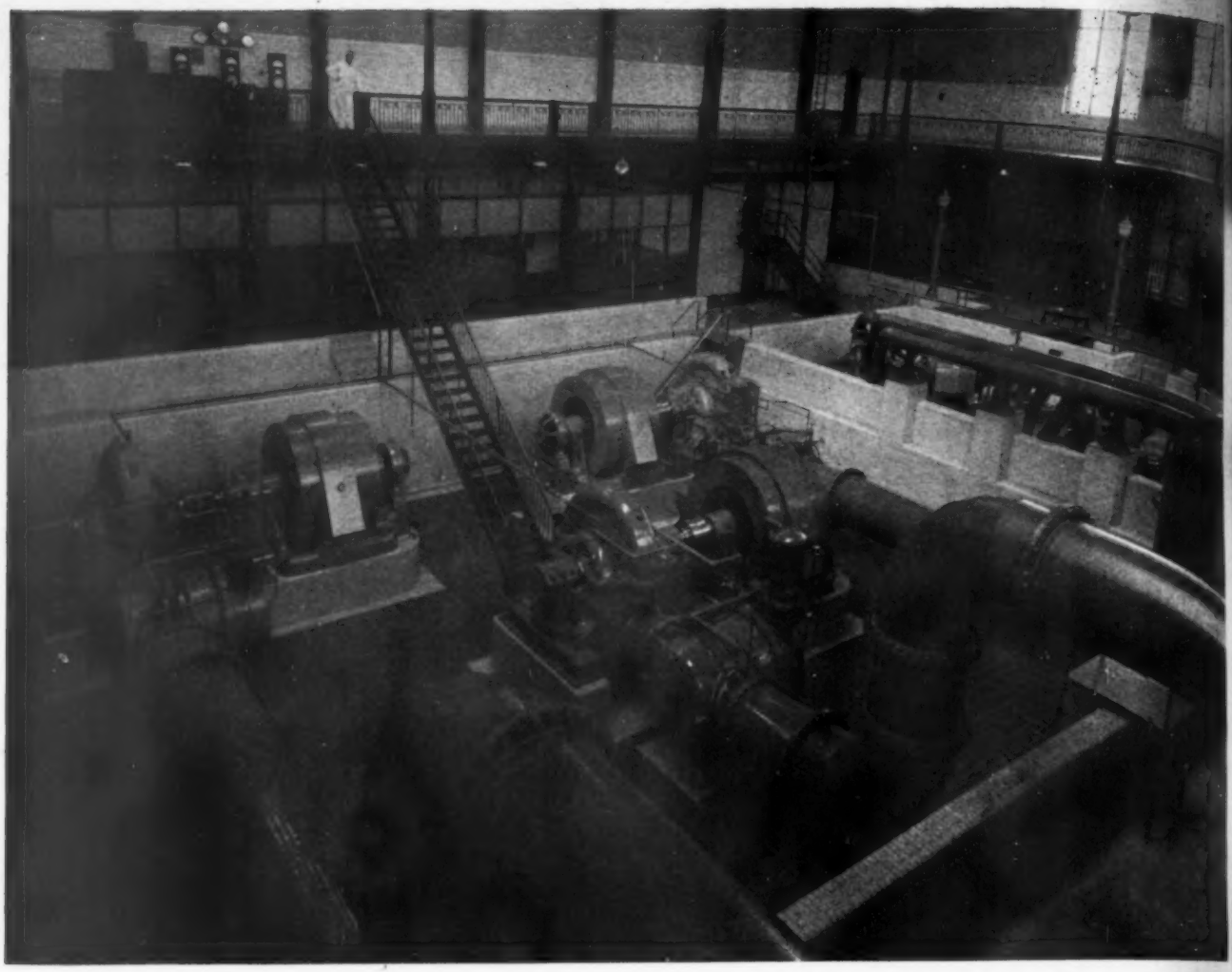
In Canada: Dresser Manufacturing Co., Ltd., 60 Front St., West, Toronto, Ont.

Houston Office and Warehouse
1121 Rothwell Street
Section 16, Houston, Texas

DRESSER MANUFACTURING COMPANY

ONE OF THE DRESSER INDUSTRIES

BRADFORD, PENNSYLVANIA



BUFFALO, N. Y.—Col. Francis G. Ward Pumping Station. Three 2500 H.P. motor driven DeLaval pumps. Each 50 m.g.d.—208 Ft. head.

1 CONTRACT — COMPLETELY INSTALLED

In 1937 the City of Buffalo, N. Y., realized the advisability of letting one complete contract for the installation of pumping equipment, 30" and 60" station piping and valves, complete wiring and controls, venturi meters, priming equipment and miscellaneous appurtenances.

One contract for all of this equipment completely installed was awarded to Turbine Equipment Company.

Turbine Equipment Company with 36 years of experience as equipment contractors are in a position to give you the same advantages of undivided responsibility in the installation of complete water works and sewage equipment.

TURBINE EQUIPMENT COMPANY

75 WEST STREET — NEW YORK 6, N. Y.

REPRESENTING AND SERVICING

DE LAVAL STEAM TURBINE CO.
DE LAVAL SEPARATOR CO.
COCHRANE CORP.
PEERLESS PUMP CO.
YEOMANS BROS. CO.

Diamond Liquid Chlorine

PREFERRED

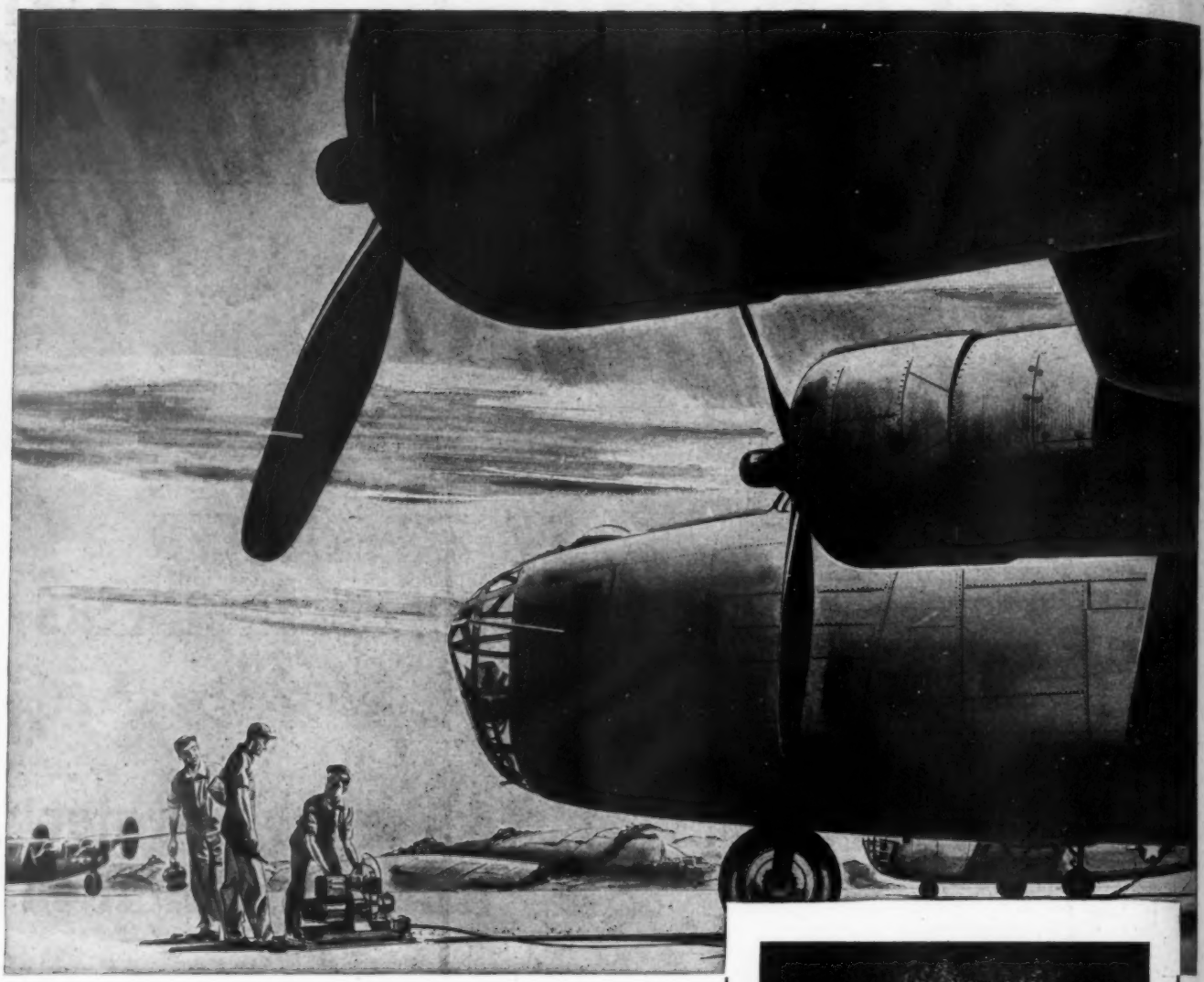
BY EXPERIENCED WATERWORKS ENGINEERS *Everywhere*

...for dependable water purification and sanitation

The more experience a waterworks engineering executive has with DIAMOND LIQUID CHLORINE, the more strongly he insists on always getting Diamond. Its dependable, uniform purity helps in the vital job of maintaining an adequate supply of pure water.

DIAMOND ALKALI COMPANY
PITTSBURGH, PA., *and Everywhere*

ALKALI



They make bombers Fighting Mad

Bombers are pretty peaceful articles resting on the ground. But up in the air they're different birds. There's fire in their eyes.

What happens between the minute a bomber rolls out of a hangar and the time it takes to the air? Brother, you should see!

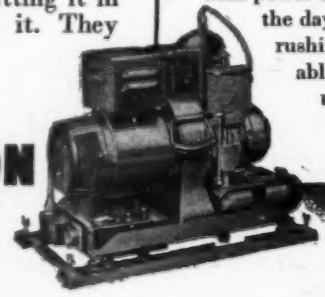
The busiest group of men you'll ever know start working on their pet. They gas her up. They stow the bombs. They check everything on the plane. And off to the side you'll see (and hear) the purr of the ground crew's faithful "putt-putt."

It's a Homelite Portable gasoline-engine-driven Generator . . . small, compact and *busy* . . . working for all it's worth, furnishing power for charging the plane's batteries and testing its electrical equipment . . . helping the boys in the ground crew to get the plane fighting mad.

It's not an easy life sparring with a bomber . . . getting it in fighting condition. But Homelites are able to take it. They do the job.

They Improve Dispositions

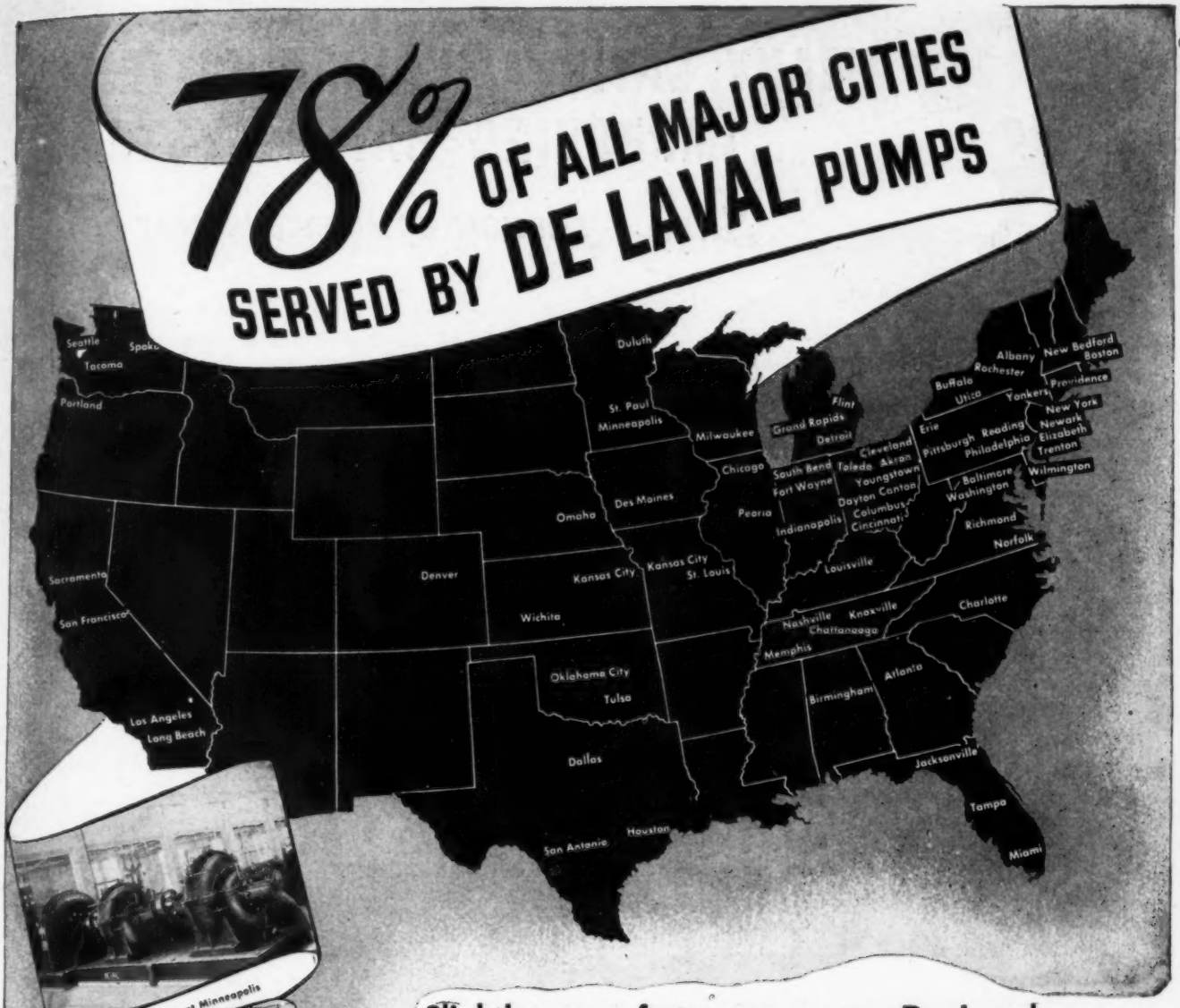
On the home front, Homelite gasoline-engine-driven generators are a blessing to busy construction men. Speeding up work with power for electric tools . . . stretching the day with night time lighting . . . rushing to emergencies with portable power . . . these Homelite units are always on the go.



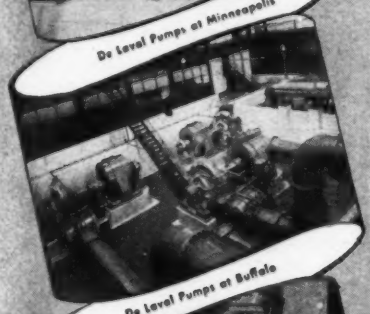
HOMELITE CORPORATION

PORT CHESTER, NEW YORK

78% OF ALL MAJOR CITIES SERVED BY DE LAVAL PUMPS



De Laval Pumps at Minneapolis



De Laval Pumps at Buffalo

De Laval Pumps at Chicago

Slightly over forty years ago De Laval introduced high efficiency, horizontally split case centrifugal pumps for water works service. Today, De Laval centrifugal pumps serve seventy-three out of the ninety-three cities in the United States having a population of over 100,000.

The record of De Laval pumps in the water works field is indeed outstanding.

4108

TURBINES • HELICAL GEARS • WORM GEAR SPEED REDUCERS CENTRIFUGAL PUMPS • CENTRIFUGAL BLOWERS and COMPRESSORS • IMO OIL PUMPS

DE LAVAL

STEAM TURBINE COMPANY · TRENTON 2, NEW JERSEY

SALES OFFICES: ATLANTA • BOSTON • CHARLOTTE • CHICAGO • CLEVELAND • DENVER DETROIT • DULUTH • EDMONTON • GREAT FALLS • HAVANA • HELENA • HOUSTON KANSAS CITY • LOS ANGELES • MONTREAL NEW ORLEANS • NEW YORK • PHILADELPHIA PITTSBURGH • ROCHESTER • ST. PAUL • SALT LAKE CITY • SAN FRANCISCO • SEATTLE TORONTO • TULSA • VANCOUVER • WASHINGTON, D. C. • WINNIPEG

"MANY LATIN AMERICAN CITIES IMPROVING WATER SYSTEMS"

Says **FOREIGN COMMERCE WEEKLY**

A campaign is being waged throughout South and Central America against waterborne diseases. Water supply systems are being improved, studies are being made and plans are being drawn for better sanitary engineering.

Particular attention is being given to areas along strategic highways; around airports and shipping centers; and in the vicinity of defense bases. These activities are part of a campaign against typhoid fever and other diseases spread by waterborne parasites.

Specific plans are taking form in El Salvador, in Mexico, in Paraguay and in the vast reaches of the Amazon Valley for the improvement or development of water supply and sanitation.

New SPECIALIZED COVERAGE

Manual de INGENIERIA SANITARIA comes as a practical Reference and Data Book to the men in Latin American countries charged with the problems of water supply and sanitation.

Printed in Spanish, it is a handbook of informative data and a buyers' guide. Published annually it gives to the advertisers year-'round reader interest and affords access to the greatest potential export market in the world today.

FIRST ANNUAL EDITION — JANUARY, 1945

INGENIERIA SANITARIA will be comparable to the English edition of the Reference and Data issue of Water Works and Sewerage, which is used by superintendents, operators and public officials throughout the United States and in many other countries.

SCHEDULE SPACE NOW — WRITE FOR DETAILS.

★

Also **CAMINOS Y CALLES**

A Spanish bi-monthly magazine (with Portuguese section) for the highway and big-job construction field. Enjoys enthusiastic reader interest throughout Latin America. CCA circulation.

Manual de
INGENIERIA SANITARIA

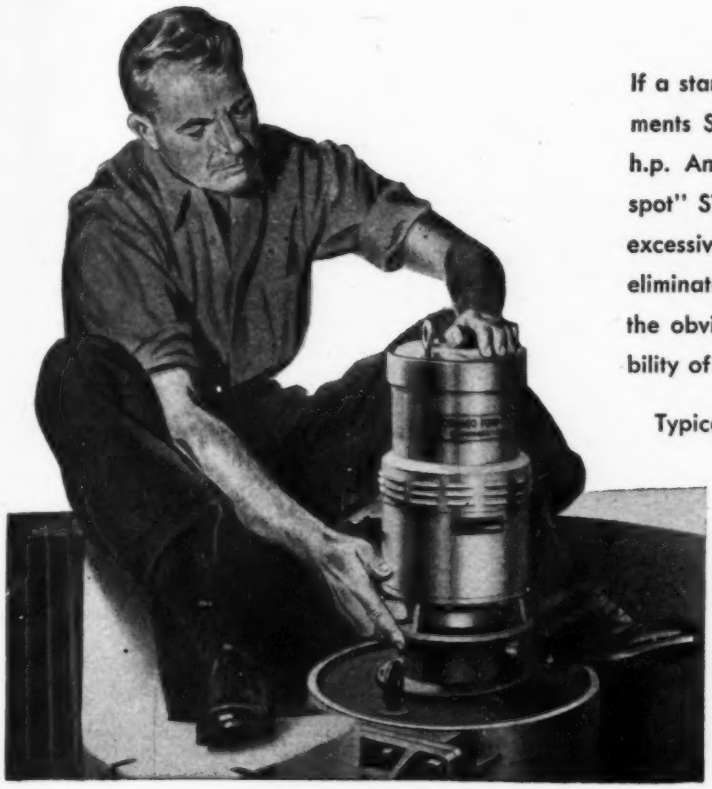
GILLETTE PUBLISHING COMPANY • 330 S. WELLS ST., CHICAGO 6

Publishers of WATER WORKS & SEWERAGE · ROADS & STREETS · CAMINOS Y CALLES · POWERS' CATALOG

CLEVELAND NEW YORK LOS ANGELES

ELECTRIC MOTORS

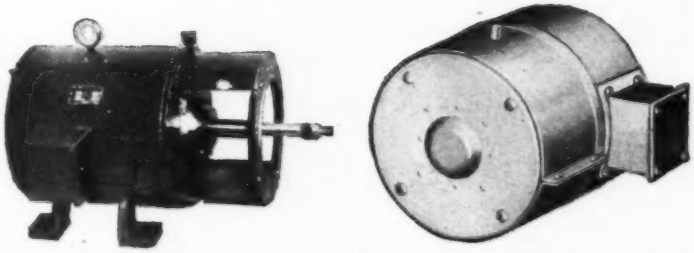
Standard or Tailored to Order



If a standard motor will meet your exact performance requirements STAR can supply it from a complete line, 1/20 to 200 h.p. And, if you need a motor tailored to fit a mechanical "tight spot" STAR can supply that too—supply it quickly and without excessive cost, because STAR'S unique welded construction eliminates the need for special castings and patterns; offers you the obvious advantages of standardized design plus the flexibility of specialized application and engineering.

Typical example of STAR engineering excellence is the motor designed and built for the Chicago Pump Company Communitor. (Illustrated at left) Hundreds of these STAR-powered communitors are in service here and abroad. They operate 24 hours a day, 365 days a year, screening and cutting sewage material automatically—keep going in spite of mechanical or weather shocks.

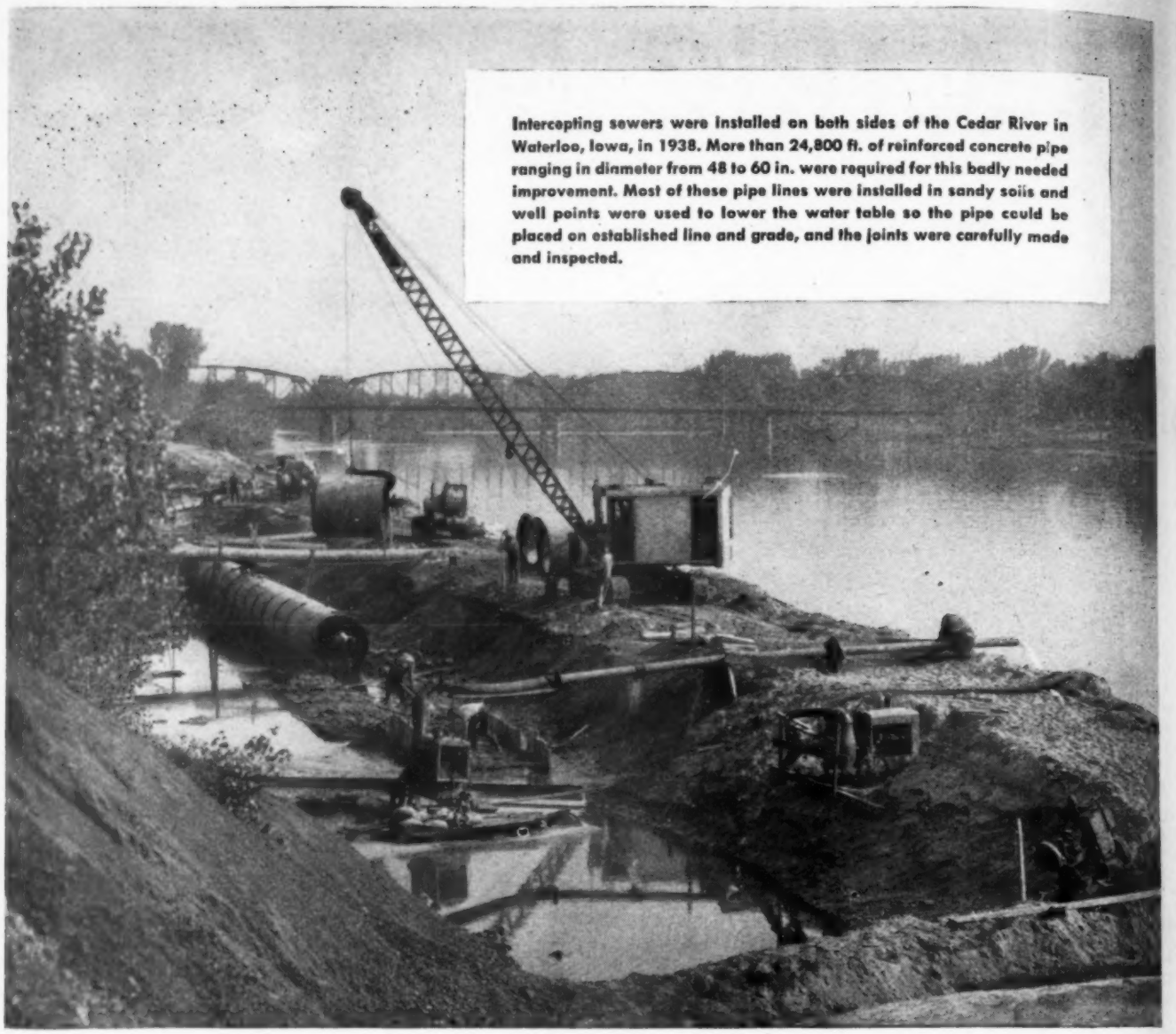
STAR ELECTRIC MOTOR CO., Bloomfield, N. J.



For 34 years STAR has provided a complete line of standard as well as specialized motors in sizes from 1/20 to 200 H.P. The motor above, at left, is a special 5 H.P. motor with end-mounting, designed for pump operation. Note special welded construction. Motor at right is another specially designed STAR motor powering one of the country's best known electric hoists. Write us about your requirements.

STAR MOTORS

POWER PACKAGED AS YOU NEED IT



Intercepting sewers were installed on both sides of the Cedar River in Waterloo, Iowa, in 1938. More than 24,800 ft. of reinforced concrete pipe ranging in dinmeter from 48 to 60 in. were required for this badly needed improvement. Most of these pipe lines were installed in sandy soils and well points were used to lower the water table so the pipe could be placed on established line and grade, and the joints were carefully made and inspected.

Concrete Pipe Sewers have

1. GREAT STRENGTH AND PERMANENCE
2. MAXIMUM HYDRAULIC CAPACITY
3. MINIMUM LEAKAGE AND INFILTRATION

For more than one hundred years concrete pipe sanitary and combined sewers have been in service in cities of the United States. When you plan sewerage improvements consult the Association or our members (list on request) who will gladly furnish technical and practical information on the construction of concrete pipe lines in open cut, in tunnel and by the jacking method.

BUY MORE WAR BONDS

AMERICAN CONCRETE PIPE ASSOCIATION

33 West Grand Avenue, Chicago 10, Illinois • 342 Munsey Building, Washington 4, D. C.

Our Fighting Boys Need Water...

Designers of the famous "Water Buffalos"

IT TAKES a lot of things, like bullets, bombs, bayonets, bazookas—and water, to win a war. Cool, fresh drinkable water in abundance. Peerless Pumps at the fighting fronts keep canteens filled—and keep our fighting men fit!

Ever since Pearl Harbor, the building of Peerless Pumps, like the building of the justly famous "Water Buffalo" Amphibian Tanks (also Peerless designed), has been an essential War Industry.

Even in the days before the war, Peerless was producing more Deep Well Turbine Pumps than any other concern in America. As the leading manufacturer in the Industry, Peerless won recognition throughout the entire civilized world. On the great ranches, farms, orchards and irrigation projects. In the waterworks of our great cities. In the vast industrial plants. Wherever water is needed, there you find dependable Peerless Pumps, operating twenty-four hours per day, year in and year out.

Now that we are meeting the tremendous war-front demand for Pumps, we hope to be able to start "digging in" on our huge backlog of orders for home needs.

TURBINE TYPE
(Deep Well)
15 to 30,000 Gallons Per Minute

HI-LIFT TYPE
Vertical Rotative Shaft Pump
Positive Displacement
10 to 60 Gallons Per Minute

HYDRO-FOIL TYPE
600 to 220,000 Gallons Per Minute

PEERLESS PUMP DIVISION—*Food Machinery Corporation*
1250 Camden Avenue, S. W., Canton 6, Ohio
301 W. Ave. 26, Los Angeles 31, California
OTHER FACTORIES: San Jose 5, and Fresno 16, California

PEERLESS

Deep Well Pumps • • •

IMPORTANT

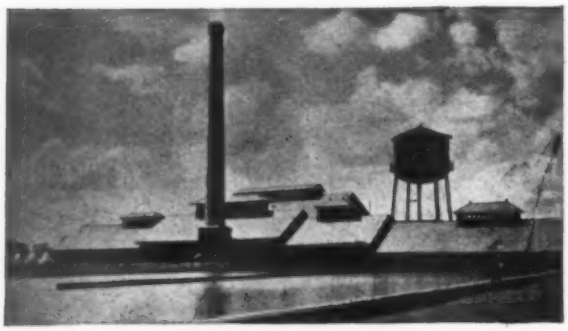
Public Health must be maintained!

The necessity of maintaining public health in war time is self-evident. Municipal officers in charge of water purification and sewage disposal have a vital responsibility in guarding the nation's health which should not be underestimated as a contributing factor to final victory.

However, the problems of maintaining public health are *becoming increasingly difficult in the face of material shortages and transportation handicaps.* General's "Alum" will help do the job right. But to ease the situation in regard to *Aluminum Sulfate* as much as possible, won't you place your orders as far ahead as you can so that we may schedule our production on an efficient basis.

Why Most American Cities Prefer General Chemical Aluminum Sulfate

General Chemical Aluminum Sulfate is an especially developed "Alum." High quality and constant uniformity have given it a *time-tested* reputation among water works engineers and sewage plant operators, who know its reliability through experience.



★ FOR WATER WORKS

1. Makes water crystal clear.
2. Longer filter runs are obtainable.
3. Is economical, used properly will conserve chlorine supplies . . . because it does not require oxidation to make it effective.
4. Superior in tests against other coagulants.
5. High in quality, its constant uniformity can be counted upon.

★ FOR SEWAGE PLANTS

1. Clean, easy to handle and economical to use.
2. Simple application, requires only low cost feeding apparatus and minimum attention.
3. Clear, colorless effluents are possible.
4. Precipitated sludge digests readily.
5. Treated digested sludge dries quickly, without odor.

GENERAL CHEMICAL COMPANY

GENERAL CHEMICAL COMPANY

40 RECTOR STREET, NEW YORK 6, N. Y.

Technical Service Offices: Atlanta • Baltimore • Boston • Bridgeport (Conn.) • Buffalo • Charlotte (N.C.) Chicago • Cleveland • Denver • Detroit • Houston • Kansas City • Milwaukee • Minneapolis New York • Philadelphia • Pittsburgh • Providence (R. I.) • St. Louis • Utica (N. Y.)

Pacific Coast Technical Service Offices:
Los Angeles • San Francisco • Seattle, Wenatchee and Yakima (Wash.)

In Canada: The Nichols Chemical Co., Ltd. • Montreal • Toronto • Vancouver

OLIVER UNITED FILTERS INC.

New York 18, N. Y. 33 W. 42nd Street | San Francisco 11 California | E. Long, Ltd. Orillia, Ontario | Chicago 1, Ill. 221 N. La Salle Street | Western Sales Div., Oakland 1, Calif., 2900 Glascock Street

Factories: Oakland, Calif. — Hazleton, Pa. — Orillia, Ont., Canada — Melbourne, Australia

PRODUCTS

Oliver Continuous Vacuum Sludge Dewaterer.
Olivite Acid-Handling Pump (Centrifugal Pump for Handling Chemicals).

EXPERIENCE

Oliver United engineers pioneered the development of continuous vacuum dewatering for the various types of sludges produced in treatment plants. They cooperated with consulting engineers and sewage plant officials in working out coagulation methods to make these sludges amenable to mechanical dewatering.

ADVANTAGES OF CONTINUOUS VACUUM DEWATERING

The benefits of mechanical sludge dewatering are such that *every* community, wherever practical, should plan to adopt this method of handling sludges. Briefly, here they are:

1...space required for the filter station is very much less than that required for equivalent capacity in drying beds.

2...the filter operates continuously, regardless of weather conditions.

3...sludge is handled more easily and at any convenient time.

4...nuisance factors are eliminated.

5...filter station easily kept clean.

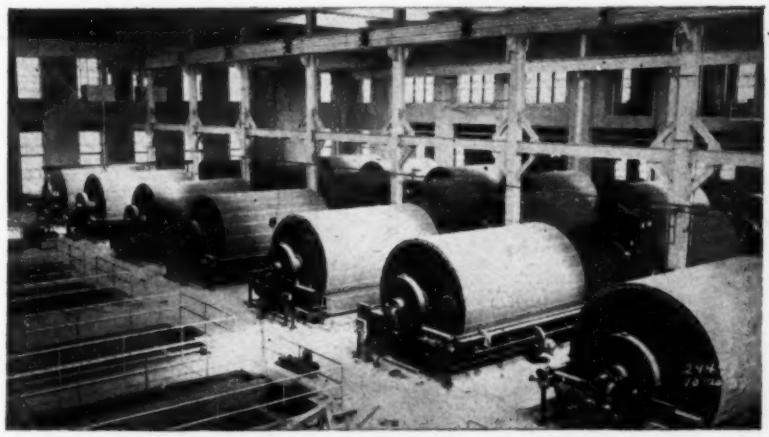
6...filter and accessories have exceptionally long life; some Olivers have been in service continuously for 20 years.

OLIVER UNITED INSTALLATIONS

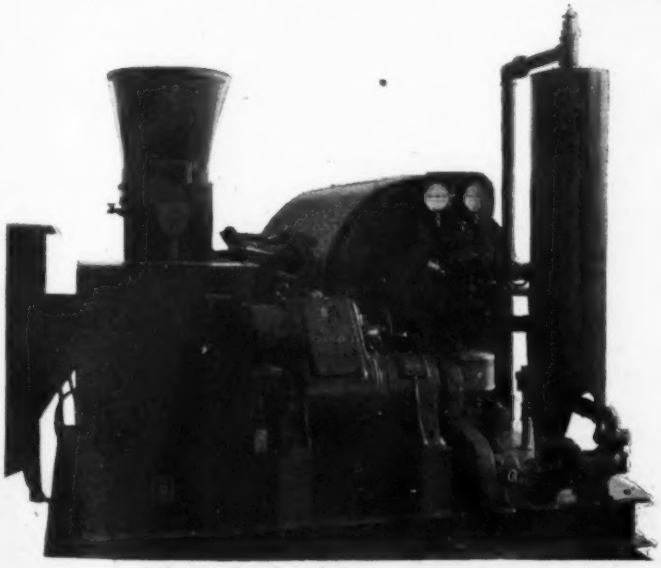
Since 1924, when the first Oliver Continuous Vacuum Sludge Dewaterer was installed, Oliver United engineers have engineered and manufactured about 125 continuous vacuum dewaterers with filter area totalling some 55,000 square feet. Sizes installed range from 54 square feet to 800 square feet. Two different stations—Milwaukee and Chicago (Stickney)—have 24 and 32 large Olivers respectively.

Following is a partial list of the cities operating sewage treatment plants equipped with Oliver Continuous Vacuum Sludge Dewaterers:

Chicago (Stickney)	32	Oliver	Filters	Greece, N. Y.	2	Oliver	Filters
Pasadena, Calif.	4	"	"	Greensboro, N. C.	2	"	"
Oklahoma City, Okla.	2	"	"	Minneapolis-St. Paul	6	"	"
La Porte (Indiana)	1	"	"	Sayreville, N. J.	2	"	"
West Haven, Conn.	2	"	"	New York (Coney Isl.)	1	"	"
Atlanta, Ga.	2	"	"	Gastonia, N. C.	2	"	"
Fort Dodge, Iowa	1	"	"	Perry, Iowa	1	"	"
				Rockford, Mich.	1	"	"



Part of the 32 Oliver installations at Chicago (Stickney)



Oliver all-assembled Sludge Dewaterer for use in small treatment plants.

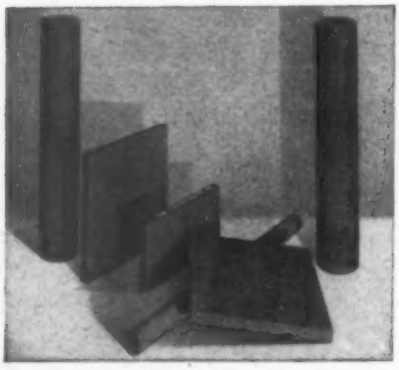
SLUDGES HANDLED

Continuous vacuum dewatering is practicable for handling the following sludges:

Raw Waste Activated
Raw Primary
Digested Primary
Digested Mixed Raw and Activated
Chemically Precipitated
Water Softening
Water Softening and Sewage
Tannery Waste and Sewage
Many Industrial Wastes

HERE'S THE WHOLE STORY ON "ALOXITE" POROUS MEDIA

The best known and most widely used in America's Water and Sewage Treatment Plants



FOR SEWAGE AND WATER AERATION

"ALOXITE" DIFFUSER PLATES

Standard size is 12″ x 12″ x 1″. Nominal stock carried. Special 12″ x 6″ x 1″, 17¼″ x 7½″ x 1″ and other sizes available on order.

Permeability recommended for all applications is 30 to 60 (use highest where clogging conditions are bad and easy cleaning desired).

Furnished within ±10% of mean permeability specified.

"ALOXITE" DIFFUSER TUBES

Standard sizes are 4¼″ O.D. x 3″ I.D. x 24″ long and 3″ O.D. x 2″ I.D. x 24″ long—Nominal stock carried. Moulds available for other sizes which can be made on order.

Permeability recommended for all applications is 35 to 65.

Furnished within ±10% of mean permeability specified.

FOR WATER FILTRATION

"ALOXITE" UNDERDRAIN PLATES

For Gravity and Pressure Type Rapid Filters and Softeners.

• Standard plain plates are 11⅞″ x 11⅞″ x 1¼″ (serving 1 foot square) carried in stock—Special plates for odd size and circular filters made to order.

These are for the false bottom construction where plates are bolted to concrete, timber or steel supports—grade is extremely coarse—but correct for supporting sand, anthracite or zeolite material.

• Standard channelled RSF plates are 11⅞″ x 11⅞″ x 3″, carried in stock—Special shapes upon order. Channels serve as distribution laterals.

These are bolted directly to filter floor—grade of material as above.

"ALOXITE" FILTER TUBES

For Direct Filtration—usually industrial non-potable supply.

Many sizes available to fit equipment or capacity specifications low (5) to medium (30) permeability normally recommended.

For supporting diatomacious filter-aid material—sizes available as above. Medium (30) permeability recommended.

For further detailed data—write for special bulletins covering all products.
The Carborundum Company, Refractories Division, Perth Amboy, N. J.

Porous Products by CARBORUNDUM TRADE MARK

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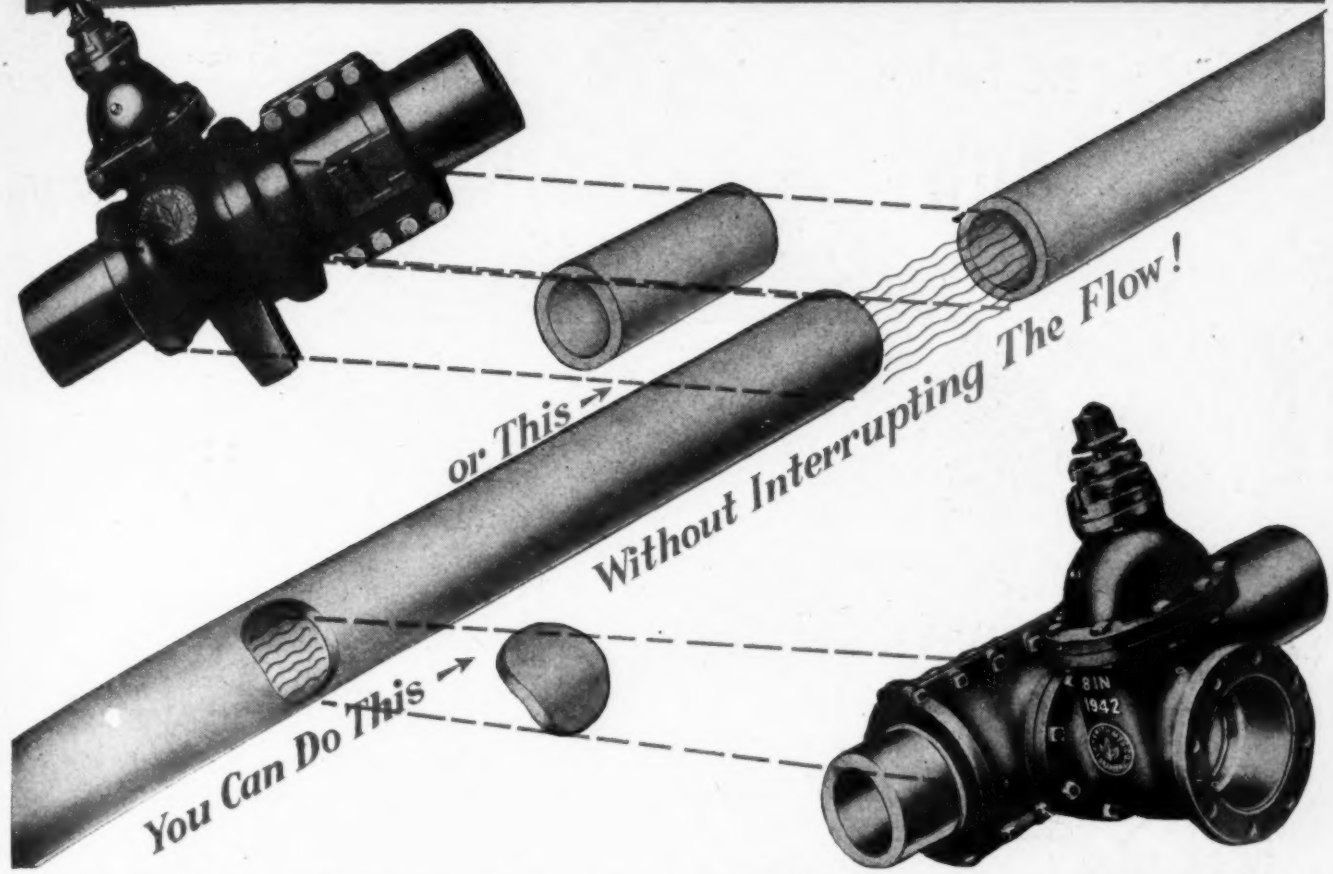
TWO IMPORTANT CONTRIBUTIONS By SMITH to the Water Works Field

Maintain Vital Flow—Without Shutting Down!



In your planning of postwar extensions, these two SMITH contributions can play a very vital part. Their usefulness has been proven over a great many years by some of the most progressive water departments in the country. The same engineering developments common to these two useful devices is characteristic of the entire SMITH line of water works equipment.

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in a full range of sizes for use with Smith Tapping Sleeves and Valves are available for purchase or rental. These machines permit the connection of branch lines 2" to 42" to any size of main or tank carrying oil, water or gas without interrupting the service. Machines can be hand or air operated.

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make it possible to insert gate valves from 4" to 36" into existing main lines without shutting down the line or interrupting the service. Information on both of these useful machines and on other SMITH products can be had by writing for Catalog 42M for water and 42G for gas.

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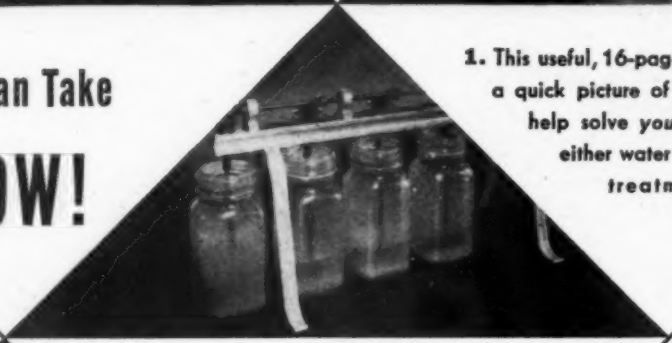
3 STEPS
To More Efficient Coagulation

1. This useful, 16-page book will give you a quick picture of how Ferrisul may help solve *your* problems in either water or sewage treatment.

You Can Take NOW!



2. With this handy, portable equipment, Monsanto technical service men will be glad to run preliminary laboratory tests on samples of your raw water or sewage.

3. Finally, all the necessary equipment for a *full-scale* plant test of Ferrisul is at your service plus the help of Monsanto's experienced technical staff.

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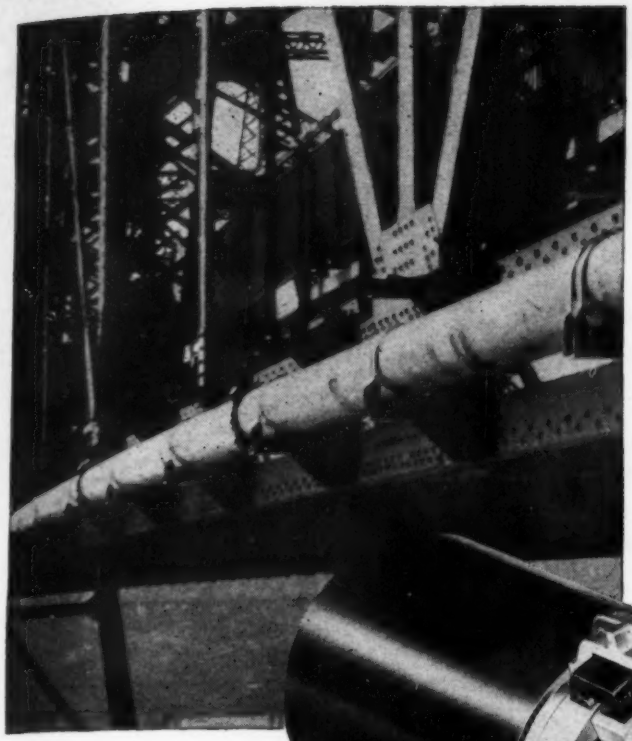

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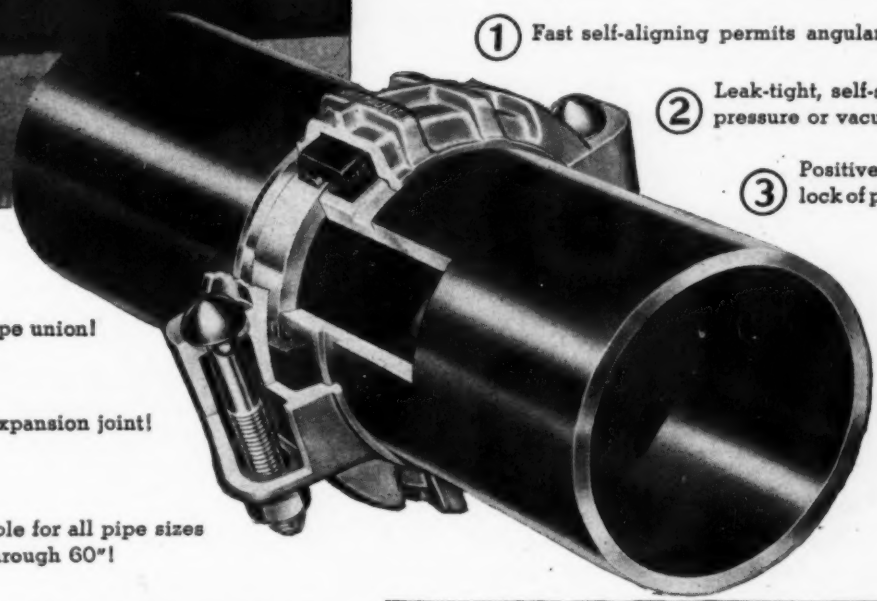
Add up all the ideal specifications you'd make for a pipe coupling and what would you have? A coupling that would join two pieces of pipe together in a leak-tight joint quickly! A coupling green labor could use! A coupling that would be flexible enough so you wouldn't have to bother about accurate pipe alignment! That would give you positive mechanical lock and yet provide for expansion and contraction! The only thing about such a coupling is that . . . Brother it's no dream. It's a Victaulic. And it has more advantages than any "pipe dream" you ever had. For instance . . .



(1) Fast self-aligning permits angular deflection!

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(3) Positive mechanical lock of pipe lengths!

(4) Every joint is a pipe union!

(5) Every joint an expansion joint!

(6) Available for all pipe sizes 3/4" through 60"!

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★ **Lower installation cost . . . unskilled labor can do the job!**

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★ **Victaulic flexibility absorbs mis-alignment, ground subsidence and traffic vibration!**

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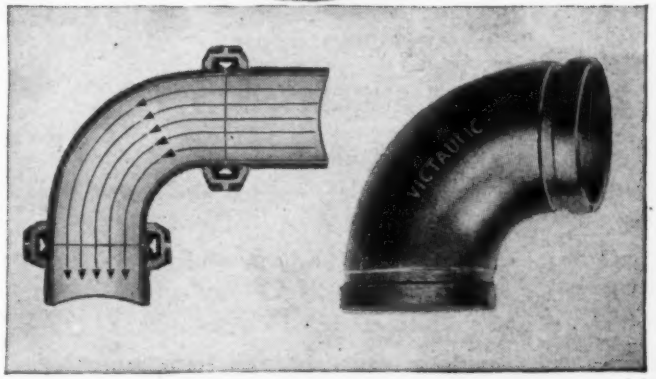

VICTAULIC FULL-FLOW FITTINGS. Full-flow diagram at left illustrates efficiency principle used in Victaulic 90° Elbow, long sweep . . . smooth, true-circular walls with no internal projections, no pockets. Lower frictional losses mean increased delivery, lower pumping costs. Victaulic makes all styles of fittings for every piping need. Be sure to specify "Victaulic."

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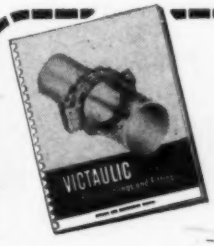

NEW VICTAULIC CATALOG MANUAL

. . . a must for every firm that uses pipe. Contains all you need know about Victaulic Couplings and Full-Flow Fittings. Write to nearest address for your copy today on your firm's letterhead. Victaulic Company of America, 30 Rockefeller Plaza, New York 20, N. Y.; Victaulic Inc., 727 West 7th St., Los Angeles 14, Calif.; Victaulic Co. of Canada, Ltd., 200 Bay Street, Toronto.

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FLINT DAM, KEARSLEY CREEK, MICHIGAN, 1928
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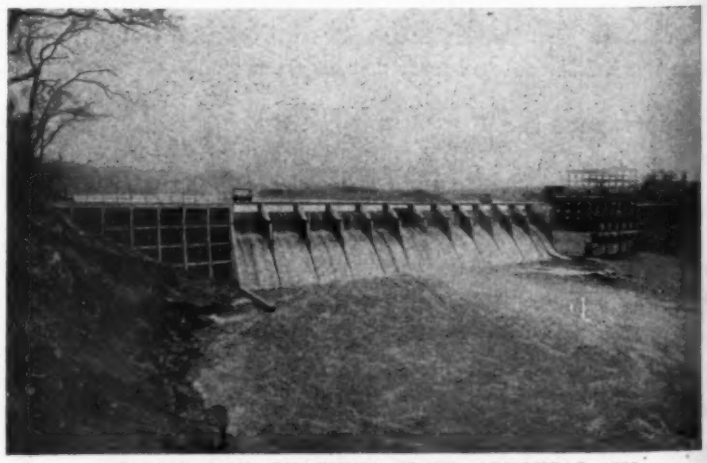
WOODLAND DAM, ST. CROIX RIVER, MAINE-CANADA BOUNDARY, 1912
St. Croix Paper Company; storage. Rock foundation

STONY GORGE DAM, ORLAND IRRIGATION PROJECT, CALIFORNIA, 1928
U. S. Bureau of Reclamation. Built across a geological fault



REMMEL DAM, OUACHITA RIVER, ARKANSAS, 1924
Electric Bond & Share Company; hydroelectric plant. Rock foundation

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To help win the war!...and the peace to follow!

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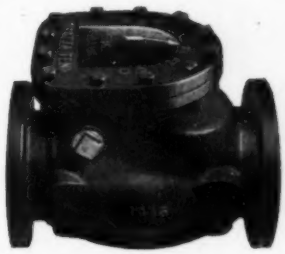

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A-25601 MUD VALVE

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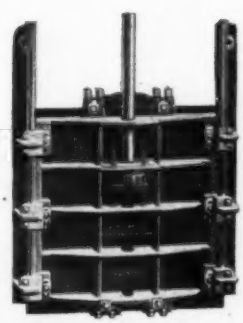
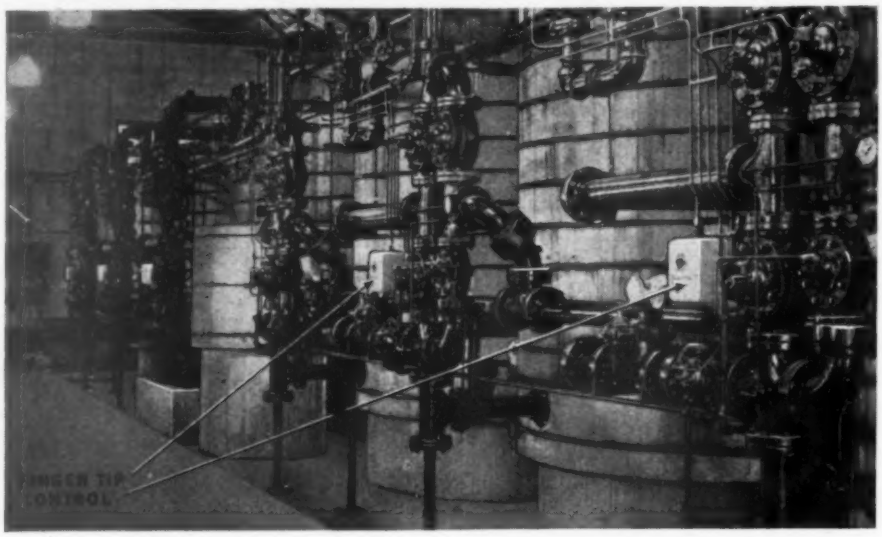


RECTANGULAR
SLUICE GATE



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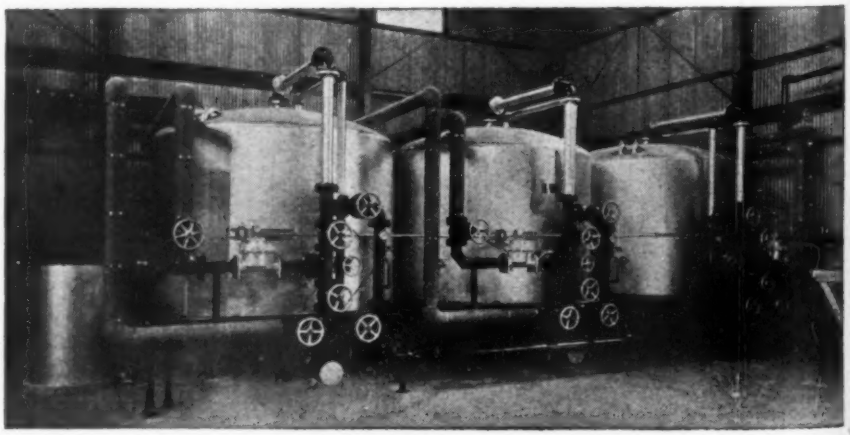

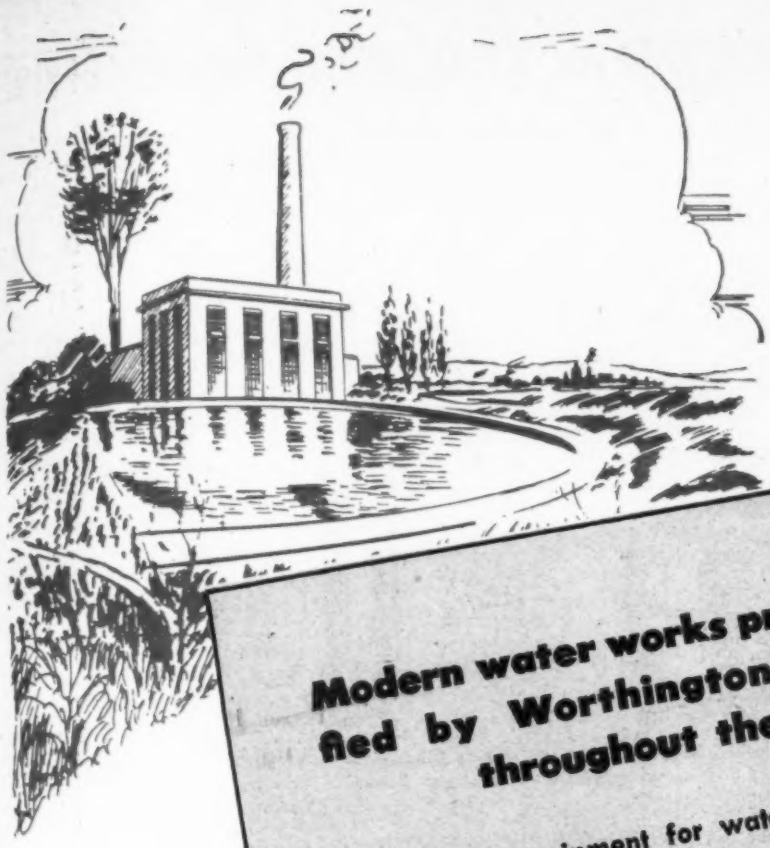

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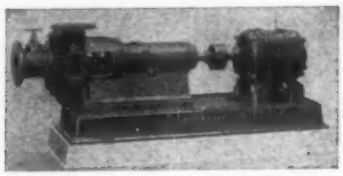

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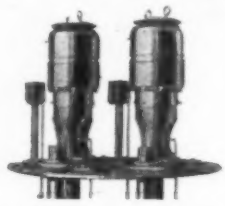

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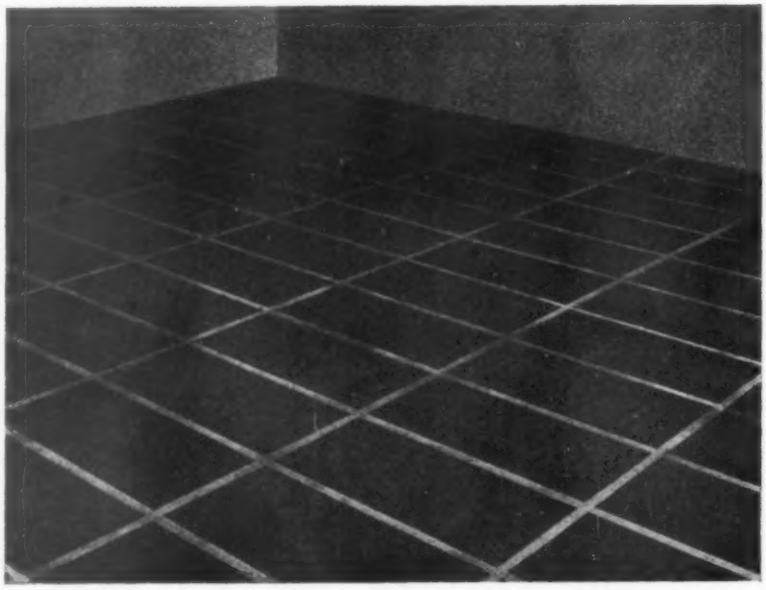

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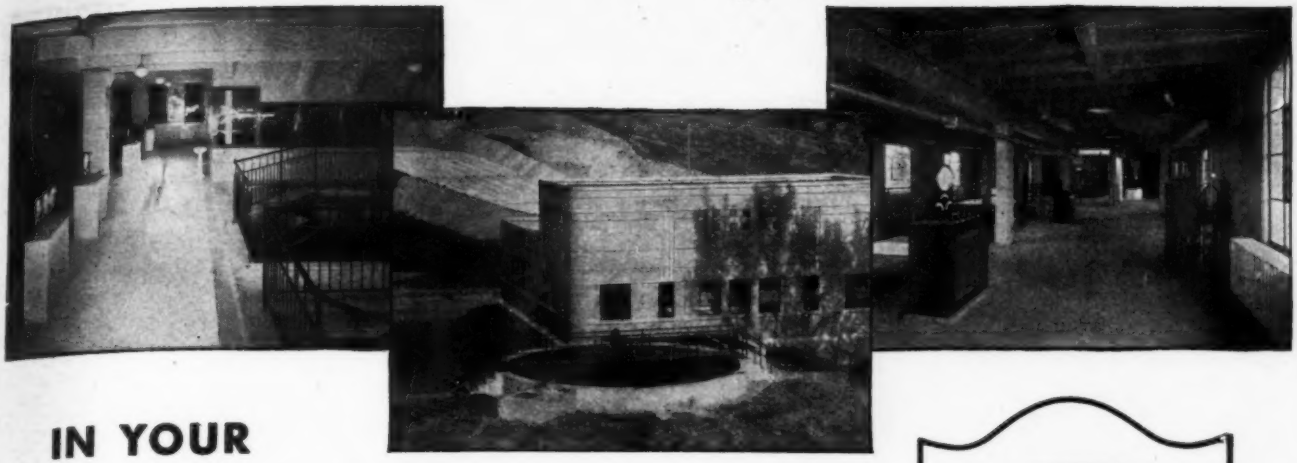

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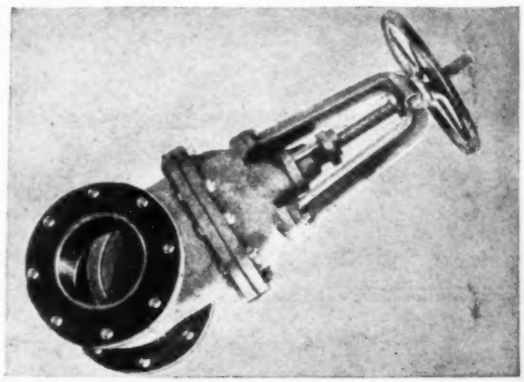

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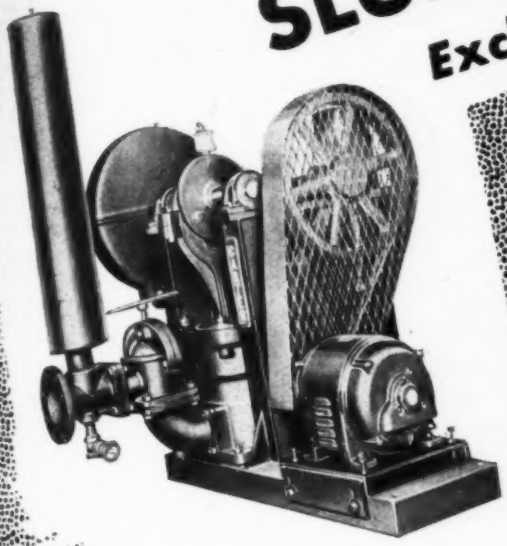

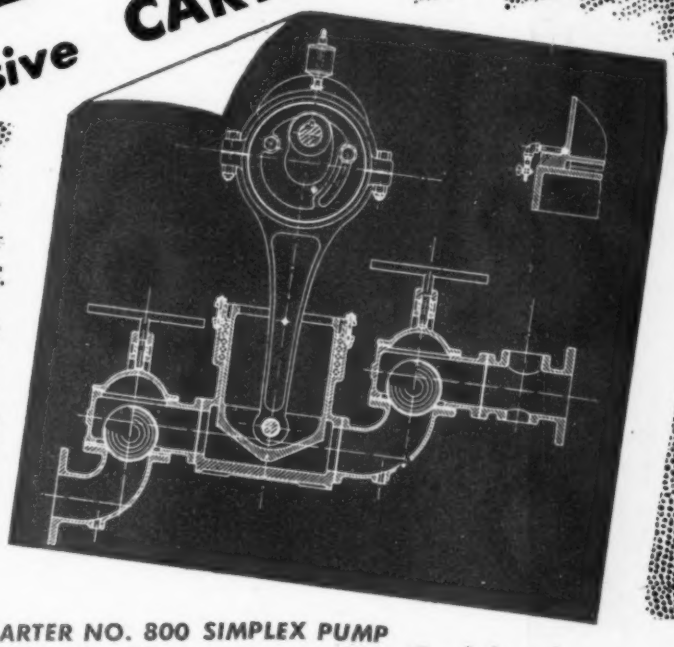

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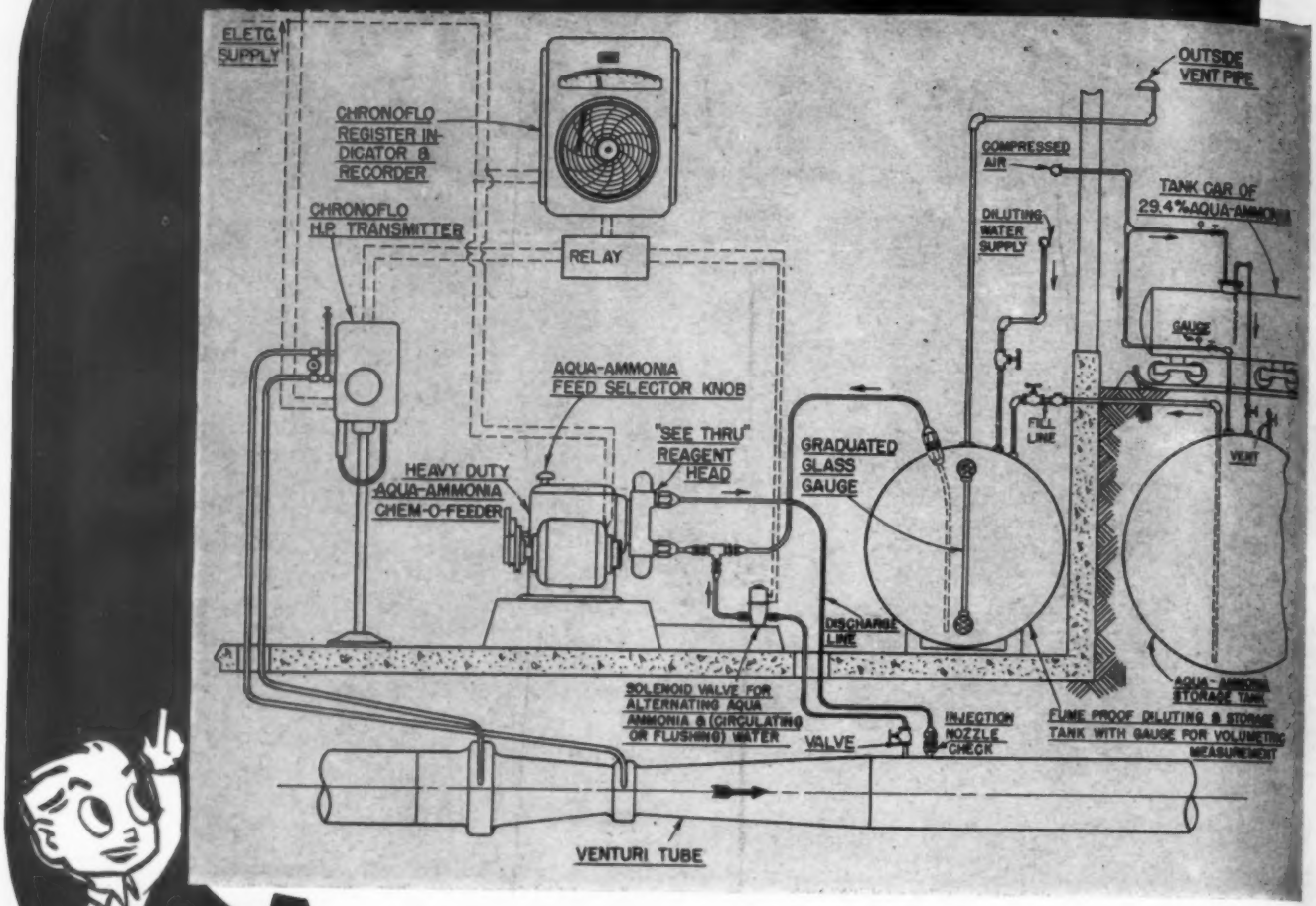

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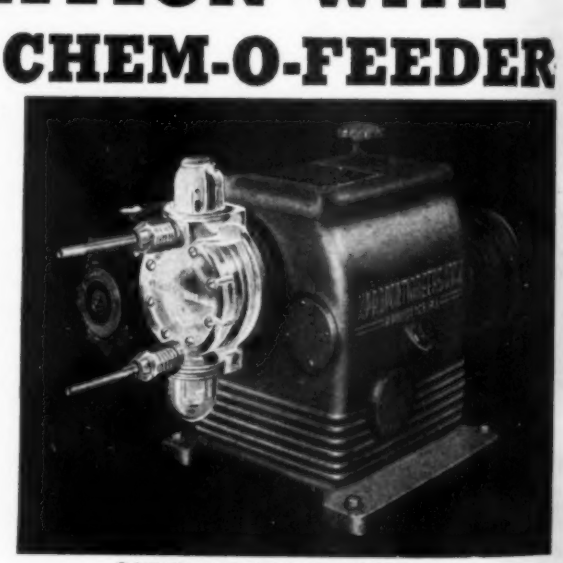

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COMING!

Cement Lining Water Mains in Place

Relates experience at Palm Beach and W. Palm Beach, Fla., with the Tate Process of cleaning old water mains and lining them in place with cement mortar. Two separate projects, involving more than five miles of cleaning and lining in each instance, serve as the basis for this article which reveals the distinctive merits of this method of recovering and permanently maintaining carrying capacity, low friction and insuring freedom from rusty water complaints. The author is—

RALPH W. REYNOLDS, Manager,
West Palm Beach Water Co., Florida.

Depreciation

Is a never ceasing topic of interest in utility accounting, and this is the subject of a thorough discussion in respect to depreciation accounting in water works practice. Involved in the study to be reported is a nation-wide survey of methods and practices as now applied by representative water utilities, with a discussion of the good and the bad—as it exists in present day practice—and suggested remedies looking toward uniformity in depreciation accounting in the water supply field. The author is—

N. T. VEATCH, Jr., Consulting Engineer,
Black & Veatch, Engrs., Kansas City, Mo.

"Accounted-for Water and Unbilled Revenue"

Describes a scheme developed for the purpose of estimating with fair accuracy the accounted-for and unaccounted-for water and unbilled revenue at any desired time, without up-to-the-minute reading of the meters. Currently the idea is of interest and usefulness because of the prevalent practice of skip month reading and rendering of estimated interim bills to customers. In short, the procedure makes possible a close estimate of the unseen registration of individual meters at any time between actual readings. The contributor is a long experienced water works manager.

"Problems in Sludge Handling"

Is a title which needs little interpretation for many of our readers. How such problems have been alleviated, if not completely solved, is told by an author who has had his share of such problems and working out their solution. He is—

CHAS. R. VELZY,
Greeley and Hansen Engrs., New York
(Formerly a Plant Superintendent)

"Rejuvenating Rock Wells"

Is an account of the successful application of basically the same methods employed in the development or rejuvenation of sand and gravel wells to rock wall wells. In all instances when the method has been applied the result has been a gratifying increase in yields from these rock wells. The author, who is co-chairman of A.W.W.A.'s Committee on Deep Wells and Deep Well Pumps, is—

J. ARTHUR CARR,
Supt. of Water, Ridgewood, N. J.

Distribution Studies

Charts for determining equivalent pipes and loop flow distribution have been developed to furnish a quick and easy method of computing these sought for values in utilizing the Hardy Cross method for determination of flows in networks. Extending the simplification of the Hardy Cross method as presented by D. R. Taylor, in the June, 1943, issue of "Water Works and Sewerage," this article shows how these charts may be applied to the examples given in Mr. Taylor's article as well as to other problems.

H. W. CLARK, City Engineer,
Niagara Falls, N. Y.

The Value of Sewage Treatment Plant Records

Has been nowhere better proven than at Kenosha, Wis., where used to advantage not only in plant control but also in connection with a court case regarding the presence of copper bearing wastes in the sewage, causing cessation of proper digestion of the sludge. This case, now before the Wisconsin Supreme Court, has received nation-wide attention. The story of the case and which plant records played in it, comes from—

H. D. RUDGAL,
Supt. of Sewage Treatment, Kenosha, Wis.

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WATER WORKS & SEWERAGE

VOL. 91. No. 6 *A Gillette Publication* JUNE, 1944

STANDARDS FOR WATER SERVICE

By MARSDEN C. SMITH
Chief Engineer
DEPT. OF PUBLIC UTILITIES
RICHMOND, VA.

IF YOU call your electrical contractor and ask him to furnish and install a 10 hp electrical motor, he knows the service standards of the local electric utility and can order the motor with assurance that your installation will be successful.

But what of the engineer, architect or plumber, when asked to furnish and install plumbing or other water consuming equipment. What is the standard pressure, and what size service line and meter does the local water utility require?

The Author

Inquiries have shown that only a few water supplies have standards for either. Many of those questioned suggest that this lack of standards is due to the diversity in procedure in various cities and this, in turn, causes the individual to hesitate to assume the responsibility of voluntary action.

This diversity of practice must be admitted, but that is no reason for us to fail to set up standards; for surely, just as the electrical companies have found it often necessary to do, we can change these standards if found to be wrong.

Pressure Standard

It is obvious to anyone that the most desirable pressure to select as the "standard" is that pressure at which the total cost of water service in the area served shall be a minimum. Unfortunately, that pressure is not as simple to determine as it is to define. Most privately owned residential property consists of structures that use water at not more than 30 feet above the sidewalk. If to this 30 feet of elevation we add an allowance of 16 feet for friction loss from the main to the outlet, it is evident that a standard pressure of 25 pounds per square inch at the sidewalk level should be adequate for residential areas.

But the heights of apartment and business buildings vary through such wide limits that the problem here becomes one of determining how high in the air the water utility should agree to deliver water. Perhaps it is fortunate that we have an upper limit of 50 psi as a fairly well established maximum for general use. This results from the well-known fact that excessively high pressures are objectionable, even if available without pumping, because such pressures result in excessive leakage, create troublesome water hammer and unreasonable plumbing maintenance cost.

Hence it appears that the operator may rationally select as a standard pressure at the sidewalk any value between the limits of 25 and 50 pounds. In accepting these limits, the operator finds that he may reasonably agree to deliver water to any height above the sidewalk that he may elect between 30 and 85 feet.

But since it costs real money to pump water, and since leakage is increased with increasing pressure, the operator must find justification for the increased operating expenses created with each pound over the minimum necessary that he selects for his standard pressure.

It may be of interest to follow some of the threads of thought that were used in one city in determining its standard pressure.

Basis of Determining Standard Pressures

Fire services are highly important, but it is surprising to many to see how relatively small a reward is to be had by increasing main pressures. Surely, none but the smallest community can rely on general service pressures for fighting any but unimportant fires. Instead, either mobile fire pumps (engines) or a separate fire system must be available. Hence, if an adequate quantity of water is available at 25 psi, and since the engine is not appreciably helped by 50 psi rather than 25 psi inlet pressure, there can be no incentive on this score for the higher pressure standard.

It is true that sprinkler systems will generally need more than 25 pounds at the sidewalk. But surely this additional pressure can be furnished by the owner of the sprinkler installation at a vastly more equitable cost than by raising the pressures throughout the entire area.

And then, as to the number of properties satisfactorily served within the limits that we have set up. Since the minimum will give reasonable service to an

Man's fundamental and almost instinctive belief in fair play forces me to thank the editor for publishing this article. The questions discussed are of great importance and have not, certainly not in recent years, received the attention they merit. But they are in their nature controversial, and hence the editor may be opening the way to a rather heated "round-table" discussion.—THE AUTHOR.

But that is just what is wanted and needed, so let's have your comments.—THE EDITOR.

average three-floor building, it is evident that by far the larger number of outlets in most communities can be successfully served by the minimum pressure now being considered. Of course, the per cent of total use that will be included between the two limits of 25 and 50 pounds will be different in every city. Thus it is certain that if there is a large part of the total use at elevations near the upper limit of 50 pounds, it is highly probable that there will be yet a large part of the total use that it has been determined to be unreasonable to supply without auxiliary building pumps.

Consequently, the only consideration from the standpoint of the consumer, both in normal use and fire protection, is how many buildings will be served by any increase above the 25-pound minimum, and how far does the water utility wish to go in assuming this increased pumping expense.

On the other hand, we should not lose sight of the fact that if we are to maintain a minimum standard at all points of a system, certainly we must exceed that minimum in most of the area served. Topography rarely, if ever, is so ideal as to cause the natural elevations to compensate for pipe friction between the supply and the consumer. And certainly it is unwise to have too many separate pressure areas; these not only are expensive to create, but a multiplicity of "dead-ends" is one of many undesirable results. Thus, even if we select 25 pounds as our standard pressure, it is certain that most of the area will of necessity have pressures considerably in excess of this minimum.

However, it must be recognized that an actual sidewalk pressure of 25 pounds can hardly be supported as reasonable for the modern town or city. And so, admittedly, rather as a compromise than from any exact scientific deduction, 35 pounds at the sidewalk was made the standard water service pressure.

The city does not guarantee that this pressure will always be available, but it assumes responsibility to make such improvements as may be necessary to maintain this minimum when service is normal. But every consumer is notified that the existence of pressures greater than this standard, no matter how long they have been or may yet be available, are above normal and may at any time be reduced to the standard.

In practice, this standard is extremely helpful to all parties. For example, if a fire service is installed which is approved by the Fire Underwriters because of

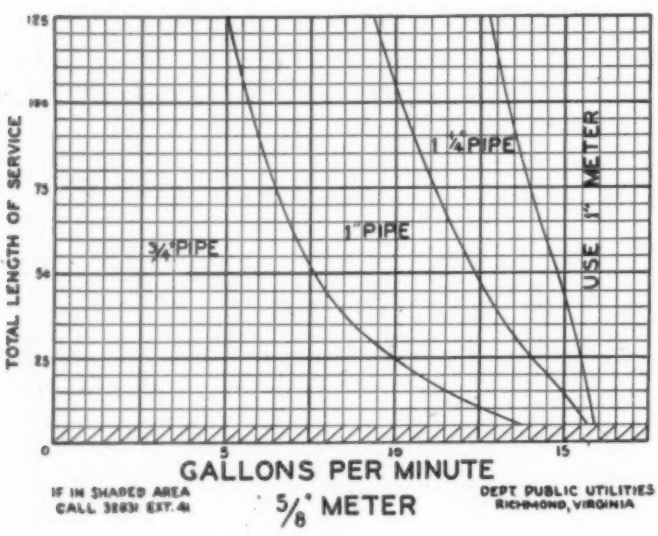


Chart I

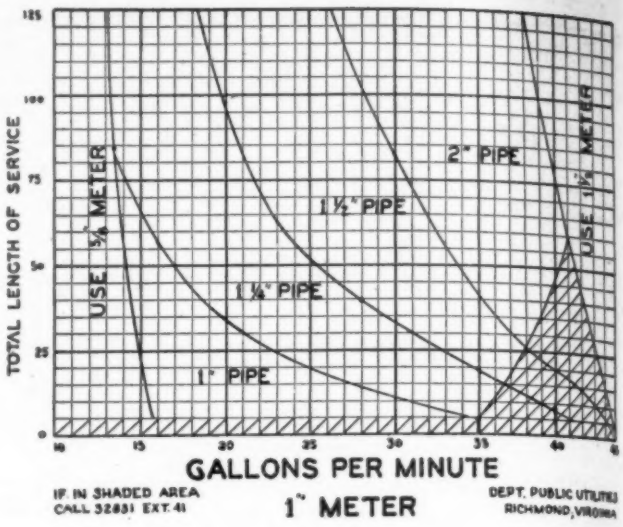


Chart II

an existing pressure of 50 or more pounds, the property owner is notified that the city does not guarantee to continue service at that pressure and that it recommends that provision be made to add fire pumps if in the future the city finds it advisable to reduce pressures to the standard of 35 pounds. The owner thus avoids the necessity of installing the pumps at the time of constructing the fire system, but if they become necessary, they may be installed in the future at much less expense if provision is made for them at the time of construction.

Size of Services and Meters

If now pressures are to be set at a value that leaves no great margin for satisfactory service, the size of the service and meter to be used must be accurately determined for each installation. But it was first necessary to decide what part of the available standard 35-pound pressure should be allotted to the friction losses in the meter and service pipe. While this presents a highly involved study, if it is to be scientifically determined many considerations indicated that a design which would consume 7 pounds of head would be rational. Consequently there is a proper combination of meter and service pipe size (the quantity of water and the total length of service pipe being known) through which the friction loss will not exceed 7 pounds.

If the water is to be used at a constant rate, no serious problem is presented in selecting the most economical combination of meter and service pipe to deliver that quantity at a 7-pound loss. But this ideal is rarely if ever obtained in practice, and so in the accompanying tables an effort has been made to allow for the diversity of use in such a way as to simplify the problem, yet not seriously err from the most successful and yet economical design.

The use of these data can best be understood by reference to actual examples. But, here it should be noted that the rates of flow are not the actual quantity of water that may be supplied to any appliance; this is because of the influence of the diversity of factors in any installation that is large enough to approach the capacity of the smallest meter and service that it is practical to use. Also, the apparently erratic value assigned to the multiplier in Table II for outlets numbering between 19 and 50 may be observed. This is the result of an effort to cover the transition from the larger residences with their relatively few occupants

to apartments with their greater number of persons per outlet.

The Cost of Services and Meters

The problem of determining the actual cost of individual small services is much too involved for practical application. In some instances a single service is installed, whereas in others a hundred or more may be grouped for the various units of a real estate development. Not only does this variation make the estimate of the cost a highly involved process, but the cost of repaving varies through even wider limits. And so in Table III the *average* cost of any service up to and including 2-inch meters with 3-inch pipe are given.

By coding all such cost collectively, it is easy to determine whether or not the money being collected for the services on the flat charge basis is greater or less than the actual cost. If, because of a major change in the cost of material and labor, the units of Table III need to be revised, a revision is made if it is believed this change of cost will be effective for a sufficient length of time to warrant the change, but not until after 90 days notice to all licensed plumbers and contractors to the effect that such a revision is planned.

Examples of Application

Through the use of Table I and a list of equipment to be installed the plumber who estimated on the cost of water service for a residence in the 5400 block, Grove Ave., Richmond, Va., determined the highest possible demand in the following manner:

(A) Two baths, each having one tub and shower, one lavatory and one toilet.
(B) One bath having a lavatory and toilet but no tub or shower.
(C) One kitchen sink.
(D) One laundry tub.
(E) One furnace connection.
(F) Three silcocks.

Appliance	Outlets	Gals. per minute
(A) Tubs	2 × 2 = 4	2 × 6 = 12
(A) Lavatories	2 × 2 = 4	2 × 4 = 8
(A) Toilets	1 × 1 = 1	1 × 4 = 4
(B) Lavatory	1 × 2 = 2	1 × 4 = 4
(B) Toilet	1 × 1 = 1	1 × 4 = 4
(C) Kitchen sink	1 × 2 = 2	1 × 5 = 5
(D) Laundry	1 × 4 = 4	1 × 8 = 8
(E) Furnace connection.	1 × 0 = 0	1 × 0 = 0
(F) Silcocks	3 × 1 = 1 (Max.)	3 × 3 = 3 (Max.)
Total	19	48

Then by reference to Table II, for the 19 outlets he found the multiplier to be .21. He then multiplied the

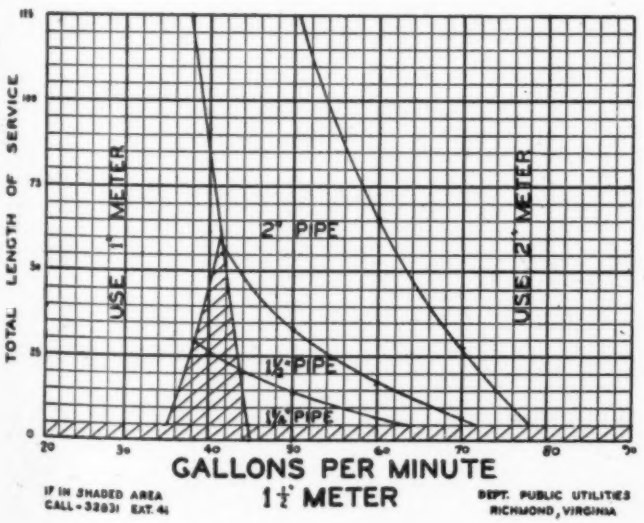


Chart III

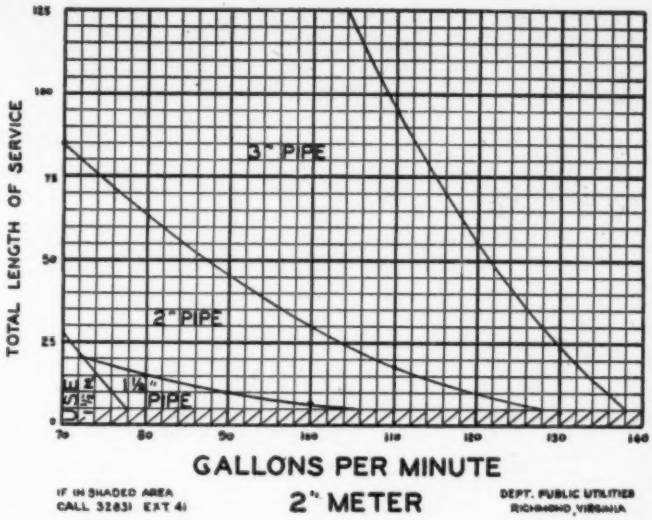


Chart IV

maximum demand by this multiplier (48 × .21) to obtain the maximum demand of 10 gpm. as the flow to be expected sufficiently often to warrant designing the service for such flow. The factors listed in Table II are what may be called "most probable numbers," in that they are based on the most probable use of combinations of the 19 outlets simultaneously.

He next determined the total length of the service, which is the actual distance from the main in the street to the point in the house where branches take off from the service pipe. In this case the house is set back 20 feet from the property line and the first riser from the

TABLE I

Demand of Various Appliances

Appliance	Number of outlets	Gals. per minute
Domestic kitchen sinks	2	5
Commercial kitchen sinks	2	7
Shower or shower and tub combined	2	6
Tub or tub and shower combined	2	6
Lavatory	2	4
Tank toilet	1	4
Domestic laundry tubs	4	8
Silcocks	1 (Max.)	3
Furnace connections	0	0
Steam table sinks	1	6
Soup kettles	2	20
Coffee urns	1	5
Potato peeler	1	8
Dish washer	2	8
Glass washer	2	6
Slop sinks	1	3
Drinking fountains	0	0

The supply of water to Flushometer toilets and urinals should be treated separately from the standard appliance in accordance with the following schedule:

No. of Units	Toilet GPM	Urinal GPM	No. of Units	Toilet GPM	Urinal GPM
1 or 2	30	2	15 to 30	75	8
3 to 5	45	4	31 or more	90	12
6 to 15	60	6			

TABLE II

Demand and Load Factors

Total No. of outlets	1	2	3	4	5	6	7	8	9
Multiplier	1	.75	.635	.575	.52	.465	.415	.375	.345
10	11	12	13	14	15	16	17	18	19	20
.32	.30	.28	.26	.25	.24	.23	.22	.22	.21	.22
21	22	23	24	25	26	27	28	29	30	32
.22	.24	.26	.28	.30	.32	.33	.33	.34	.34	.34
34	36	38	40	42	44	46	48	50	55	60
.34	.34	.34	.34	.34	.34	.34	.34	.33	.32	.31
65	70	75	80	85	90	95	100	More than 100		
.30	.29	.28	.27	.26	.25	.24	.23	.22		

TABLE III

Estimated Cost of Services Including Paving

FOR CLASS I PAVING

(Paving that does not require concrete base, including all alleys, penetration and plain spall paving)

Service Length (ft.)..		10	15	21	26	31	37	46	55
Street Width (ft.)....		0-26	26-35	36-45	46-55	56-66	67-80	81-100	101-120
Pipe Diameter (Inches)	Meter Size	COSTS							
¾	⅝	$ 41.25	$ 51.00	$ 62.75	$ 72.50	$ 82.00	$ 94.00	$111.50	$129.00
1	⅝	43.25	53.00	65.00	75.00	85.00	97.00	114.50	132.50
1¼	⅝	48.00	58.00	71.00	81.50	92.00	104.50	123.50	142.00
1	1	58.00	68.50	80.50	90.50	100.00	112.00	130.00	148.00
1¼	1	63.50	73.50	86.50	97.00	107.50	120.00	139.00	157.50
1½	1	69.00	80.50	94.00	105.00	118.00	129.00	149.00	169.50
1½	1½	94.00	107.00	120.50	131.50	143.00	156.00	176.50	196.50
2	1½	105.00	119.50	135.00	148.00	161.00	176.00	199.00	222.50
2	2	234.00	247.00	262.00	275.00	288.00	305.50	326.50	350.00
3	2	289.50	305.50	325.00	340.00	357.00	376.00	405.00	433.50

FOR CLASS II PAVING

(Paving that does require concrete base—i. e., all paving other than Class I)

Service Length (ft.)..		10	15	21	26	31	37	46	55
Street Width (ft.)....		0-26	26-35	36-45	46-55	56-66	67-80	81-100	101-120
Pipe Diameter (Inches)	Meter Size	COSTS							
¾	⅝	$ 60.00	$ 80.50	$104.00	$123.50	$143.00	$166.50	$201.50	$236.50
1	⅝	63.50	83.00	107.00	126.50	146.50	170.05	206.00	242.00
1¼	⅝	68.50	89.50	114.50	135.00	156.00	181.00	218.50	256.00
1	1	79.00	98.50	122.50	142.00	162.00	186.00	221.50	257.50
1¼	1	84.00	105.00	130.00	150.50	171.50	196.50	234.00	271.50
1½	1	91.00	113.50	140.00	162.50	184.50	211.50	251.50	291.50
1½	1½	116.00	140.50	167.00	189.50	211.50	238.50	278.50	318.50
2	1½	128.50	155.00	185.00	209.50	234.00	264.00	308.50	353.00
2	2	257.50	282.50	312.00	336.50	361.50	391.00	435.50	480.00
3	2	316.00	345.00	380.00	409.00	438.00	473.00	526.00	578.00

service is 52 feet from the front of the house, or 72 feet from the property line. The main is to be 6 feet south of the center line of the street and the house is on the north side of the 66-foot wide Grove Ave. The length of service from the main to the property line will be one-half of the 66 feet plus 6—or 39 feet. The total length of service, therefore, is 72 plus 39 or 111 feet. Referring to Chart I, we see that a 1-inch service pipe with a ⅝-inch meter is all that is needed for this service required to supply 10 gpm.

This example is used because it is a borderline case. Although a 1-inch pipe with a ⅝-inch meter will be sufficient, reference to Table III with Class 2 paving under a 66-foot wide street indicates the price of this service to be $146.50, whereas a 1¼-inch pipe with ⅝-inch meter will be only $9.50 more. This slight difference in cost fully justifies playing safe and installing a 1¼-inch service pipe instead of the 1-inch line.

Example 2

A service building is to have the following equipment:

12 Toilets (Flushometer)
4 Urinals (Flushometer)
17 Lavatories
17 Showers
1 Kitchen sink
1 Coffee urn
2 Drinking fountains

Again the number of outlets and the maximum demand were determined from Table I.

Appliance	Outlets	Gals. per minute
Lavatories	17 × 2 = 34	17 × 4 = 68
Showers	17 × 2 = 34	17 × 6 = 102
Sink	1 × 2 = 2	1 × 7 = 7
Coffee urn	1 × 1 = 1	1 × 5 = 5
Drinking fountains	2 × 0 = 0	2 × 0 = 0
Total	71	182

Here there were 71 equivalent outlets and a potential maximum instantaneous demand of 182 gallons per minute. From Table II, under 71 outlets, the factor applied indicates 182 × .29 = 53 gpm., to be the maximum demand to be assumed for all appliances other than the flushometer toilets.

To this was added the expected demand of the toilets and urinals, which was determined from Table I as follows:

	GPM
12 Flushometer toilets	60
4 Flushometer urinals	4
Other appliances	53
Total	117

The distance from the main to the first branch piping in the building is 50 feet. From Chart III it is seen that to carry 117 gallons 50 feet requires a 3-inch service pipe with a 2-inch meter.

Assume this service to be supplied from a main in a brick paved alley 20 feet wide. To determine the cost from Table III of Class 2 paving under the column headed "Street Width 0-26 feet" and on the line for 3-inch service pipe and 2-inch meter, find the average cost to be $316.00.

Note: All of these designs and schedules of cost were based on the use of Type K copper pipe and bronze meters and have had to be temporarily modified during the existing state of war.

Favorably Accepted by Master Plumbers

Sets of the four graphs reproduced with this paper are supplied Richmond plumbers and contractors. It is noted that a telephone number appears on each chart so that the estimator may obtain further information, interpretation or guidance in the use of these charts.

This method of determining costs and design has been most favorably accepted and has proven entirely successful in all cases in which it has been used.

A WATERWORKS "SEABEE" WINS HIS SPURS

And Wants to Know After the War What?

By ROGER ESTY
Superintendent
WATER AND SEWER BOARD
DANVERS, MASS.

"GOOD-BYE boys, we'll be seeing you soon. Kinda keep an eye out for my wife and little boy. Keep me posted as to how they are. Well—so long—and 'keep 'em flying' 'til I get back."

These were the parting words of a young water works man leaving the home-front for the armed forces of his country—your country, and my country.

This young man of twenty-eight years has been required to give up a good job, a home, a wife and baby boy—freedom and security, to make this country safe and secure in the future for these most prized possessions of his.

Walter Lang, an employee of the Danvers' Water and Sewer Board, only one of millions of other boys—perhaps yours and mine—that have given up similar prized possessions, desires, ideals, and dreams of the future, due to the devilish desires of a couple of guys named Tojo and Hitler; and the third, that gone but not forgotten, Mussolini.

When next heard from this young man was at Williamsburg, Va., where he was to receive his so-called boot-training. Fortunately, he was assigned to the water supply detachment. Little did he realize how valuable his few years in the water works field were going to be for him in the days to come. Being assigned to water supply, he was taught how to locate a suitable water supply, how to set up pumps and chlorinating apparatus, and how to provide storage facilities for the treated water.

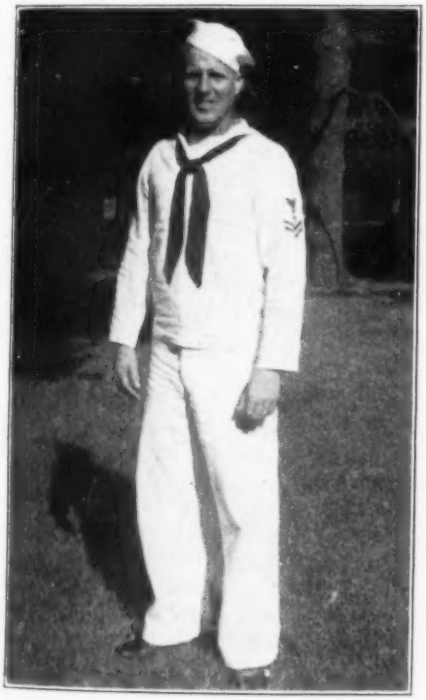
The Author

We have heard often about men in the armed services who have been given jobs entirely foreign to their civilian training and experience, but this is the story of a water works man who was "discovered" by the Navy, put to his highest use and, thereby, made even a better water works man.

But it is more than that. It is the story of how a man learns, of his resourcefulness, and of the value of knowing where to ask questions when help is needed. It is also the story of what a service man thinks about the future, about returning home, about a job after the war.

We echo Roger Esty's closing lines where he says, "Read this young man's letter . . . ponder and ask yourself if you are doing all you possibly can in getting projects and jobs ready for these fellows when they come back home. . . . Are you ready for them?"

We say: If you're not getting ready, many "Walt" Langs are going to wonder about the deal given them, and what meaning this "Blueprint Now!" movement, which they have been reading about, has had other than what it will be—namely, just ballyhoo, and a promise unfulfilled.



Walter Lang MM 1/c
(Another Stripe Has Since Been Added)

It was not long after this that we received a letter from him, enclosing one of those mailing addresses so familiar to all of us now—A.P.O.—c/o Fleet Post Office, etc. Then, we knew that he was off.

Then those long days of waiting. Finally a letter and from its contents we assumed he was in Alaska, but where—no one knows yet. That, of course, remains a military secret.

Our "King of the Klondike" Loses Some Sleep

Our former employee was immediately assigned to the water works job of running a little pumping station on one of those small mountain streams so common in that country. Given a jeep to run around in on the job, now he was surely the "King of the Klondike."

It wasn't long before he had his first trouble call; and, true to form, it came in about 2:00 A.M. "Wake up, Walt! Something's happened to the water system, the pressure's gone completely."

Into his clothes, into the jeep and

Laying Transite Pipe "Somewhere in the Far North"

up along the mountain stream to the pumping station, where the difficulty was soon located. The very fine screen used to keep out sticks, leaves, fish, etc., had become clogged with hair washed down from the grazing grounds of the elk and the deer. Cleaning the hair from the screen wasn't too difficult and water again passed through the screening chamber into the pump well where the pump immediately picked up the water again. Back came the pressure over the system, and back to bed went our Seabee!

And He Learns About Transite Pipe

Walt's next job was to lay several thousand feet of Transite water pipe. No one in the camp had ever had any experience in laying this type of pipe and few of Walt's buddies had even seen this type of pipe before.

Walt had laid Transite sewer pipe with the customary poured bituminous joints on his old job back home, but never had any experience in the laying of Transite water pipe. They tried caulking the rubber rings into the sleeve as you would yarn a bell and spigot cast iron pipe joints. Of course that didn't work. They next tried compounds (a la' sewer pipe joint) and that didn't work either. By now they were getting pretty nervous and desperate. The pipe just had to be laid and still no one could be found who knew the trick of inserting those rubber rings.

A Call for Help

I had always told my men the following: "Remember this, boys, you can never get stuck. There is always some way out of every difficulty. If you do not know yourself how to solve it, find somebody that does—someone that has the necessary knowledge, material or equipment."

So with this in mind, Walt decided his best bet was to write home to me. And so the letter came, telling me his troubles. This was his first real job and he was quite worried apparently for he didn't want to fall down on it.

That letter caught me flat-footed, too, for I had never used this kind of pipe for water either, but I had seen it laid and knew that some of my water works friends had used it. So I had to start practicing what I had been preaching, "if you do not know yourself, contact someone that does." I picked up the telephone and called a superintendent in a neighboring town and told him about the letter I had just received. I asked him if he could help me out. "I surely can," was the reply, "Come right over and I'll give you all the information and experience I've had with it."

I guess he must have got busy at once for when I arrived at his place about a half hour later, he had two lengths on the shop floor with the sleeve and rubbers all on, ready for a demonstration. He very kindly showed me how it was done and all of the "tricks" that he had learned in the handling and laying of it. He took his catalogue and one that I had and we cut out all of the necessary pictures and instructions that we felt would help out our friend up North to do the job.

I hustled back to Danvers, pasted the pictures and instructions on some sheets of paper in their proper order,

Two-Room Cottage at Dam

(Sea-Bee Walter Lang—one of the "Can-Do Boys" who do the difficult immediately but take a little longer for "the impossible.")

numbered them, and then proceeded to write a six-page letter describing the entire operation. I suggested that he set some pipe up on the banking first and practice doing it before he attempted to do it in the trench. Six hours after I had received his letter my letter of pictures and instructions was thousands of feet up on the way.

We watched the mails every day for a letter from him telling how he had made out. It wasn't long before we received a letter from him, telling us how he had received our instructions and pictures and to prove that they worked out all right he enclosed some pictures showing the completed job, the pipe and gates all laid and set satisfactorily. One of these pictures is here shown.

He was surely proud of the job he had done and you can bet we were proud of him, too. To him, at first, this seemed almost like an impossible job, but by using his head he showed his superior officers that he just couldn't get stuck and that he could take anything they could hand out. That's the good old water works spirit that is so prevalent in the water works field.

Walt Wins His Spurs

The outcome of this job was that they made Walt superintendent of the water works system at the post, and apparently, from all indications, he is also operating the town water system. It must have paid him good dividends because now he has another stripe on his sleeve and believe me we are as proud of it as Walt is.

Walt's letters are full of interesting stories and experiences in running a water works system in the far North. Material and experienced men are scarce and he is getting some very valuable experience in water works construction, maintenance, and supervision in that small water works plant. He is surely going to be a very valuable man to us when he comes home.

Post-War Planning

You may say, "How do you know he is coming back home to the old job?" May I quote a section of his last letter and let you judge for yourself if that old job is worth anything to him, and in fact, I think you will agree that this is the *Number One* thought the boys have in mind for after the war—get home, and get back to the old jobs. I quote a section of his letter:

"Roger, I see you are on this Post War Planning.* It sounds like great stuff to me, for when we fellows come home, we are looking forward to our old jobs and hope there is enough work to keep us going. I know, I certainly hope my job is still at 17 Hobart Street. It's going to be mighty tough for some of the fellows coming home without a job. That's why I think and know you are 'on the ball' doing what you are, with this Post War Planning. I hope the people who listen to your speeches, let it sink in and believe how urgent it is and how much it means to us fellows. If they think it isn't so, tell them to contact me, and I'll give them a service man's opinion on Post War Planning." Signed: Walter Lang, MM1/c.

My friends: Just read this young man's statement again, then sit and ponder for awhile as you take another drag on that old pipe, and ask yourself if you are doing and have done all you possibly can in getting projects and jobs ready for these fellows when they come back home and walk up Main Street to greet you. Are you ready for them?

*Ed. Note: Mr. Esty is a wheel-horse member of the Joint Committee on Water and Sewage Works Development, preaching and practicing alike, for he has seen to it that "Walt" Lang and many other of the local boys will have jobs when they come back to Danvers.

CANADIAN SECTION'S MEETING LARGEST IN HISTORY

Section Continues to Grow While Enjoying Outstanding Secretarial Leadership

OPERATING smoothly, quietly and efficiently Secretary Berry of the Canadian Section of AWWA, faced with unexpectedly heavily strained facilities and accommodations, watched the registration sweep-hand whirl dizzily around the dial until the totalizer registered the record-breaking paid attendance of 555 for the 1944 conference of the Canadian Section held at Niagara Falls, Ont., April 19-21.

New Chmn.
A. L. McPhail
Supt. of Water
St. Catharines, Ont.

Retiring Chmn
T. M. S. Kingston
City Mgr.-Engr.
Chatham, Ont.

This was just 112 higher than the previous top attendance, and we believe gives the Canadian's the record for attendance at any Section meeting other than that of the California Section with its 638 members, as compared to Canada's 323. Incidentally this figure of 323 represents a gain of 37 members for the year by the Canadian Section, and that constitutes a record gain for all years save 1941 when the International Convention of AWWA was held in Toronto.

Then, even more concerned was Secretary Berry when 472 seats were required for the annual dinner attendance, necessitating seatings in an overflow dining hall and subsequent consolidation of the two groups in the banquet hall for the ceremonies and the floor show and dancing which followed. With the experienced secretarial hand and the splendid functioning of the General Brock Hotel management and staff all went smoothly—rather remarkably smoothly, we should say. However, it was evident that the Canadian Section, now third in size of all AWWA Sections (and second in size of meetings), has outgrown all but Canada's largest hotels in Toronto and Montreal.

AWWA's Pres.
Saml B. Morris
Leland Stanford
Univ.
Palo Alto, Calif.

Honored
Ross L. Dobbin
Mgr. of Utilities
Peterborough, Ont.

Next year the 24-year-old Canadian Section celebrates its Silver Anniversary and this fact presages a yet larger annual meeting, perhaps rivalling those of the Californians.

Natl. Director
W. L. McFaul
City Engineer
Hamilton, Ont.

Secy.-Treas.
A. E. Berry
Ont. Dept. Health
Toronto, Ont.

And this reminds us to say that President Sam Morris of AWWA came on from Palo Alto, Calif., to witness the prowess of the Canadian Section and make a very splendid speech along with the presentation of a $2,000 AWWA check to the Section for investment in Canadian War Bonds.

Honors and Awards

Following the annual dinner several awards were made.

To the immediate past-president, Oswald H. Scott, of Belleville, Ont., was presented the Past-President's Certificate.

To the retiring president, T. M. S. Kingston of Chatham, Ont., was presented the past-presidennt's emblem —a silver mounted appropriately en-

(Photo—Courtesy of "Water and Sewage")

The Head Table—Annual Dinner
(Taken from both ends the picture shows President Morris and Chairman Kingston twice in the center.)

A String of Past-Chairmen

J. Clark Keith, Mgr. Util., Windsor, Ont. — *N. J. Howard, Supt. Purif., Toronto, Ont.* — *W. E. MacDonald, Mgr. Wtr. Dept., Ottawa, Ont.* — *A. B. Manson, City Engr., Stratford, Ont.* — *E. V. Buchanan, Mgr. Util., London, Ont.*

graved walking stick. It had a bent handle so maybe it was a walking cane.

The Fuller Memorial Award was announced as having been voted to another past-chairman, Wm. Storrie of Toronto—the actual award to be made during the 1944 AWWA Convention

The Canadian Section's Hunt Memorial Award, recognizing noteworthy faithful services of practical water works operators, went to Harry F. Hall of Sarnia, Ont.

Membership Longevity Recognized

Those to receive certificates denoting 30-year memberships in the Association were W. M. Scott of Winnipeg, R. C. Harris of Toronto and the Public Utilities Commission of Brantford, Ont., as corporate member.

Those to receive certificates denoting 25-year memberships were: R. L. Dobbin, Wm. Storrie, C. Warder, M. N. McCrady, A. Plamondon, T. J. La Freniere, R. W. Angus, W. E. Mac Donald, C. G. Routledge, A. M. Bowman, W. B. Redfern, St. Mary's P.U.C. and "The Canadian Engineer," now *Water and Sewage.*

Certificates denoting 20 and 15-year memberships were also awarded. Active members in the 20-year group were: D. M. Hanna, R. Harrison, W. S. Lea, M. Pequegnat, E. A. Cleveland, A. L. Farquharson, W. L. McFaul and J. Wright. The corporate members were the cities of Chatham, Whitby, Guelph and Regina.

A Tribute to Ross Dobbin

An extra curricular presentation was made to an old "wheel-horse" in the Canadian Section and past-president of AWWA—Canada's highly esteemed Ross Dobbin of Peterborough, Ont. It took the form of an appropriately inscribed copy of some of the memoirs of Ross Dobbin's late father, who was long the editor of Peterborough's leading newspaper. The book, recently compiled and published by Ross Dobbin himself, bears the title "Our Old Home Town." It was presented as an evidence of esteem and affection for the recipient who responded with feeling, and assurance that his old mother at home would be gladdened even more than he to have this special copy in the family library. Then a bachelor's tear fell midst the applause of many water works friends.

Also Past-Chairmen

(Of the Section) O. H. Scott, Mgr. Utilities, Belleville, Ont.

(Of the Equip. Assn.) W. T. Randall, Pres. Neptune Meters, Toronto, Ont.

(Mr. Randall represents the Canadian Water Works Equipment Assn. on the Section's Executive Committee.)

Officers Elected

The following were elected officers:

Chairman — A. L. McPhail, St. Catharines, Ont.

Trustees—Hugh Kellner, Windsor, Ont.; F. J. Veale, Hamilton, Ont.

Those who continue as Trustees are: Geo. H. Ferguson (Ottawa), W. H. Waddell (Owen Sound), R. Harrison (Scarborough), H. S. Nicklin (Guelph).

The National Director, elected in 1943 for a 3-year term, is W. L. McFaul of Hamilton; and, it hardly needs stating that Dr. A. E. Berry was re-elected Secretary and Treas.

Entertainment

Entertainment provided by the Canadian Water Works Equipment Association included the very excellent floor show after the annual dinner, and then dancing with a buffet supper at midnight.

The novel "Water Works Club Room" was as popular as in the previous two years of its history, proving a successful "experiment" by the Canadian Water and Sewage Works Equipment Association. In this scheme the equipment group does community entertaining, rather than entertaining in individual rooms of the various firms. The Equipment Association takes over the cocktail lounge, which for the duration of the meeting, is operated by the Association, as "The Water Works Club." Here there is music, and soft drinks and beer are served as well as the more powerful refreshments. The "Club" is kept open only between the scheduled functions of the Section and afterwards until the 1 a. m. closing hour. Here everyone can find everyone else whether for "shop-talk" or just good sociability. At one end of the "Club Room" was found the Ladies' Lounge which gives tone to the whole thing.

The "Club" idea has apparently pleased the great majority, for the Executive of the Section voted its favor for the continuation of the "Club Room" at the 1945 meeting. The scheme certainly has its merit in keeping the crowd together; and, when properly done, can be quite successful, as proven in the Canadian test of three years. The success of course depends upon the Equipment Association members' pledge of no individual room entertaining, the infraction of which

Speakers and Discussors

A. L. Farquharson, Mgr. Util., Brockville, Ont. — *Harry O. Kerr, Kerr Eng. Co., Walkerville, Ont.* — *Wm. D. Hurst, Water Engr., Winnipeg, Man.* — *W. W. Rogers, Mgr. Util., Carleton Place* — *R. H. Martindale, Mgr. Util., Sudbury, Ont.*

A. V. ("Cap") DeLaporte
Ont. Dept. of Health
Toronto
and Mrs. DeLaporte

T. M. S. Kingston
City Mgr.-Engr.
Chatham
and Mrs. Kingston

Oswald H. Scott
Mgr. Pub. Utilities
Belleville
and Mrs. Scott

C. J. Des Baillets
Mgr. and Chief Engr.
Montreal Water Dept.
and Mrs. Des Baillets

would defeat the whole idea and doom its continuation.

Luncheon of Past-Chairmen With the Executive a Feature

The Canadian Section has a plan very much worthwhile in the mind of this writer, who was favored with an invitation to attend the annual Luncheon for Past-Chairmen and Officers of the Section. This luncheon is held toward the end of the meeting for the specific purpose of discussing the affairs and plans of the Section. The past-chairmen are expected to criticize current operations or management of the Section and the annual meeting, and more particularly to make suggested improvements in both.

Technical Sessions

We have taken considerable of the available space permissible for this report in telling of some of the impressions gained in the general running of the Canadian Section's meetings. As a result the reporting of papers and discussions is to be more curtailed than we should like. However, the impressiveness with which the Canadian Section functions, and with which its meetings are conducted, seemed to us the highlight which deserves any degree of prominence that can be given. With the space that remains we shall do our best in highlighting the technical discussions, and offer apologies to those participants who may perhaps feel slighted to some degree.—L.H.E.

Conservation and Postwar Planning

The opening session was devoted to the geological aspects of Canadian ground water supplies, the effects of the destruction of natural water conservation elements and postwar programs for improved conservation and water supply betterments. The first paper, that by Professor A. F. Coventry of the University of Toronto, developed the fact that no change had taken place in the quantity or pattern of precipitation in Canada during the past 100 years. The worsening conditions of earlier dependable streams which now go dry in summer and fall, and the costly floods intervening in Southern Canada, and the disturbing diminution of ground storage, could be laid to deforesting the area. He advocated bio-technical planning of reforestation and land cover plantings as a national need for safeguarding irreplaceable water supply and reducing the cost of waste treatment for correcting nuisance conditions in the depreciated streams. While proposed dams and control works might be a palliative, Professor Coventry rightly stresses the greater overall good from reforestation programs and urged consideration of such in the postwar planning under way. Leaders in the Section agreed with this idea. Surprisingly, only two water works managers present reported that reforestation had been practiced by their cities.

(Photo—Courtesy "Eng. Contract Record")

To the Retiring Chairman

A Walking Stick, but no "Walking Papers"

Here "Tommy" Kingston (center) is being presented with the past chairman's badge, a handsome cane with engraved silver band. The new chairman, "Al" McPhail, in making the presentation, has said something amusing, but our memory's bad.

"The Geological Aspects of Canada's Ground Water Resources" were presented by Dr. B. R. McKay of the Dominion Geological Survey, Ottawa. Using slides to illustrate the great variety of Canadian geological formations, and their effects in limiting any contribution of good quality water to the underground reservoir, this type of presentation is a difficult one to report. Dr. Kay's paper did show the gamble involved in depending upon ground water supply in many Canadian areas, and set forth the reasons for the generally highly mineralized waters usually encountered in well developments in Canada. He explained why wells only a relatively short distance apart may yield a markedly different quality or quantity of water. Geologically such wells may be many miles separated, while the faulted strata beneath surface contains mineralized water pockets.

A. C. Anderson
Mayor
Strathroy, Ont.
and Mrs. Anderson

Wendell R. LaDue
Supt. Water & Sewerage
Akron, Ohio
and Mrs. LaDue

Mrs. "Jim" Kinney
Mrs. George Morgan
Mrs. "Norm" Howard
Toronto

Howard E. Statham
Chairman Water Comm.
Strathroy, Ont.
and Mrs. Statham

"Post-War Water and Sewerage Programming" was introduced by E. L. Filby, Field Representative for the Joint Committee on Water and Sewage Works Development. Those who have seen the six-point program (and all should have) in the Com-

Trustee
H. S. Nicklin
City Engr.-Mgr.
Guelph, Ont.

Fuller Awardee
Wm. Storrie
Consulting Engr.
Toronto

mittee's "Blue Print Now!" brochure, will not need have these repeated here. (If any reader has not seen this brochure, prepared as a guide in post-war planning for water and sewage projects, by all means write for a copy. The request may be addressed to "Water Works and Sewerage," 155 E. 44th St., New York City, or to AWWA headquarters at 500 Fifth Ave., New York City.—Ed.)

Mr. Filby stressed the fact that if a community expected to receive government handouts for the financing of post-war projects they were not only delaying a worthy part of the general re-employment and re-adjustment program for the nation, but were most probably doomed to disappointment. The up-and-coming municipalities were proceeding with their own financing arrangements in which benefits from joint management and operation of water and sewerage facilities had been apparent. The reasons for favoring joint operation were sound technically and economically.

"A Discussion of Plans for Canadian Post-War Programmes" followed under the leadership of J. W. Peart, manager of Water & Sewerage at St. Thomas, Ont., who called in various members to report progress.

Mr. Scott, of Belleville, Ont., had $185,000 in projects including a high service reservoir, filter plant extension, duplicate river crossing mains, and a main enlargement program. He thought that the utility should do its own financing and expected to.

Mr. Martindale, of Sudbury, Ont., reported an accumulated surplus of income for use in post-war improvements estimated at $350,000, and including main enlargements and $40,000 for various plant equipment. Sudbury would not have to borrow any funds nor depend upon the Federal government for aid.

Equipment Assn. Officers

Geo. Morgan, Mgr.
Victaulic Co.
Toronto

Jas. B. Kinney, Mgr.
W. & T. Ltd.
Toronto

(Morgan is President and Kinney is Secy.-Treas. of the Water Works Equipment Ass'n of Canada; and, thereby, joint proprietors of the "Water Works Club Room," the membership card to which is the official registration badge of the Section.)

Mr. McPhail, of St. Catharines, Ont., is planning a duplicate raw-water main (16,000 ft.) to the filter plant. The size of pipe we failed to record.

Messrs. Nicklin of Guelph and Waddell of Owens Sound also had projects planned for 5 years of scheduled betterments.

Mr. Buchanan, of London, reported $250,000 in planned improvements to be financed without outside assistance. Mr. Buchanan made the splendid suggestion that municipalities should be given first chance at buying war construction equipment when such is offered for sale later.

30-Year Members

W. M. Scott
Mgr. Greater Winnipeg Water Distr.
Winnipeg, Man.

"Tommy" Hodkinson
Supt.
Water Works
London, Ont.

[The executive will follow through on this worthy suggestion.—Ed.]

Mr. MacDonald, of Ottawa, reported a million-dollar program, over a 5-year period, including a 7 mgd. addition to the filter plant. Ottawa had not been able to hold off longer on some projects, already put underway.

Mr. Nicklin, of Guelph, felt that Guelph could afford to replace 23-year-old motors and pumps, on the basis of obsolescence, and planned doing so. Likewise the standby gasoline engines and pumps, needed replacing at Guelph.

Mr. MacNicol, of Forest Hill (Toronto Suburb), is planning an elevated tank only, because they purchase water from Toronto.

Only one member (from Dundas) said that his commissioners felt that Federal aid was needed.

In reply to questions concerning conditions in the U. S. Mr. Filby stated that a few of the largest cities were trying to get Federal aid. In 20 states building up of surplus reserves by the utilities has been legalized. In most of the states revenue

Jas. C. Street
Supt. of Water
Welland, Ont.

Keith MacCloud
Supt. of Water
Stamford, Ont.

J. W. Peart
Mgr. Utilities
St. Thomas, Ont.

Prof. W. L. Malcolm
Cornell Univ.
Ithaca, N. Y.

L. G. McNeice
Mgr. Utilities
Orillia, Ont.

A. B. Chandler
Mgr. Utilities
Port Arthur, Ont.

D. G. Fraser
Ingersoll-Rand
Toronto

J. F. Woodcock and L. O'Neill of Mueller, Ltd. Sarnia, Ont. from Montreal and Toronto Branches, Respectively

Marcel Pequegnat Mgr. Utilities Kitchener, Ont. E. J. Buckley, W. J. Westaway Co. Hamilton J. C. Breithaupt Util. Comm. Chmn. Kitchener (*Now serving 45th year)*

Lockport, N. Y. Delegation L. J. Hooker Supt. of Water R. H. Foltz Supt. Filtration Fred G. Garlock Engineer J. Ray Murphy Engineer

Heads You Win!

Cyril Forster Mgr. Utilities Palmerston, Ont. and S. Howard Gillett Secy.-Treas. Util. Comm. Windsor

type bonds constitute legal borrowing and sound financing.

He cited the New York and Michigan acts which give state assistance to municipalities through paying for one-half the planning costs, the latter being limited to 4 percent of the estimated cost of the project. These acts had been very stimulating to getting to the blue-print stage and other states are considering similar legislation.

The Effect of Water Quality on Dental Caries

One of the highlights on the program which drew the largest attendance of any session was the paper by medical authorities on the influence of fluorides in water supplies on tooth decay amongst children, and the announcement that the supply of Brantford, Ontario, was to be treated with fluorides for a 7-year period as a test of the merits of fluoriding water supplies as a dental caries corrective.

The authors of the paper were Dr. H. T. Hodgins, director of Dental Services, Ontario Dept. of Health, and Dr. Harold K. Box, Research Professor of Periodontology at the University of Toronto. The paper, however, was presented by Dr. Arnold D. Mason, Dean of Dentistry, Univ. of Toronto, who was introduced by Dr. Hodgins, as President of the Canadian Dentists Ass'n.

The Hodgins-Box paper is a masterpiece from which the following are some of the highlights. The observation has been made that primitive peoples who seem to have a protective film over their teeth, do not suffer tooth decay, which is a disease of modern civilization in the day of the tooth-brush, pastes and powders. Mottled enamel observed in children develops during the first 8 years of life. It has been traced to a fluoride content of water supply in excess of 1 to 1.5 ppm. More recently, however, based on circumstantial evidence (confirmed to a degree in laboratory tests) it is being suggested that waters containing fluorides preserve teeth against decay. Field studies have pointed rather conclusively to the value of waters of fluoride content between .75 and 1.5 ppm. (Fl) as an inhibitor of tooth decay, while mottled enamel is only prevalent when more than 2 ppm. (Fl) is continuously drunk. In consequence, Brantford in Canada, like Newburgh in New York State, is to treat its well water supply with sodium fluoride to bring the content of (Fl) up to roughly 1 ppm. It is believed that the experiment to be conclusive must continue over a 7-year period, and is so planned.

The Law
Colorful "Keeper of the Door" of the Water Works Club Rooms

In the studies by Drs. Box and Hodgins the whole effect of the fluoride is apparently one of inhibiting acid production by the bacteria of fermentation and likewise inhibits the acids of the mouth should such be formed. Evidence points to the fact that the contact effect is the sole effect and metabolic consideration or influences do not enter. Therefore all individuals should receive like protection from waters, of like fluoride content. Studies of children in Canadian communities reveal the apparent marked effect of 0.5 to 2.5 ppm. (Fl) in the reduced tooth decay observed.

Dr. W. L. Hutton, as Health Officer of Brantford, as the principal discussor, stated his belief in the efficacy of fluoride in water as a tooth protection. In Brantford the City Board of Health, the Council, the Dental Society, and the Public Service Board, had agreed that the water supply fluoriding experiment should be given the proposed trial. Should mild cases of mottled enamel appear the dentist can easily remove it by bleaching.

Following this splendid and interesting presentation some questions developed from the floor concerning the policy of introducing community

H. L. Pringle Supt. of Util. and David Mowat Util. Commissioner Whitby, Ont.

Norman Gardner Supt. of Water Gananoque, Ont. and Wm. Keene Supt. Utilities Pointe Claire, Que.

Geo. H. Strickland. Supt. Filtration and Russell Armstrong Consulting Engr. Windsor, Ont. (*A. Past-Chmn.)*

T. G. Harrison and Fred J. Hodgson Water Commissioners Welland, Ont.

J. A. Donaldson Supt. of Water and E. E. Lyons Clerk and Treas. Ancaster, Ont.

medication of any sort through doping of the public water supply, both on practical as well as economic grounds. It was recalled that Rochester, N. Y., was once the "guinea-pig" when medical men thought goiter should be controlled by iodizing the public water supply. Now at far less expense to the community iodide requirements are obtained through iodized salt. Since only the contact effect is of value in fluoride treatment of water, why not secure the effect from the old-fashioned salt idea in cleansing teeth or add the fluoride to dental preparations used in mouth hygiene generally. These thoughts come principally from Messrs. Buchanan, Howard and Enslow, with Mr. Brush of *Water Works Engineering* suggesting that no water works manager attempt to medicate a public supply until a decision is made by the local medical authorities and administration to do so, and then only under exact instruction covering dosages, etc.

Problems of Public Utilities

In discussing "The Problems of Public Utilities" Ira P. Macnab, commissioner of Public Utilities for Nova Scotia, Halifax, N. S., was the first speaker. He reviewed the history of the Nova Scotia Utilities Commission, which since 1913 has been completely self sustaining, and regulates all municipal utilities of Nova Scotia as well as privately owned utilities. There is no political interference in the Commission because of its self supporting character and its rulings are equivalent to a Provincial Supreme Court Order. It defines depreciation as loss of service life not restored through maintenance, favors use of straight line depreciation (by classes of property) and permits depreciation reserves. The rate of return permitted on value of properties is determined in each instance rather than recognizing a fixed rate of return for all cases, such as 8 per cent, etc.

The Commission found rates charged by municipal utilities a matter of expediency mostly, with little justification based on facts. Mr. Macnab believes that the following should be the goal of all municipal utilities:

(1) A uniform accounting system developed.

(2) Operation completely divorced from city government.

(3) Metered rates only.

(4) Water for street flushing, fire service, public buildings should be paid for by the city from taxes.

(5) Free water to attract industry disapproved.

As to paying dividends into the city treasury, since the community is a shareholder reasonable "dividends" of this nature seem proper.

Mr. Macnab cited cases where the municipality requested authority to increase the capacity of the system, which request was denied until after metering 100%. Then it proved that no expansion of system capacity was needed.

Mr. Macnab, in reply to questions, said that they assumed the investment for fire protection to represent approximately 60 per cent of the total cost of the system and fire service charges should be based on that figure.

After retaining a reasonable surplus from earnings he believed that any further surplus rightly should go to the city as shareholder. Then if the latter grows to an unreasonable figure a rate adjustment is in order.

"The Problem of Good Water Works Management" was ably discussed by Wendell R. LaDue, Supt. and Chief. Engr., Bureau of Water and Sewerage, Akron, Ohio.

Mr. La Due, who is chairman of A.W.W.A.'s Committee on Management of Municipal Water Works, after reviewing the various forms of management for municipal water utilities, said that regardless of the form of management the manager must never forget that he is the public's servant in the last analysis. Further, that the swing to municipal operation was due to dissatisfaction with the quality of private operation. What Mr. LaDue felt to be more important than type of management was the quality of top management. Such had been evident in making a study of the good and bad in municipal water utility management in the United States. The best managers had in due time been recognized by the public and received recognition and support, whereas inferior management, regardless of the system in question, would eventually be recognized and poor management invites political interference, diversion of funds and other ills of which water managers complain. The good manager is usually satisfied with whatever system exists.

Water Distribution System Design

"Some Considerations in the Design of Water Distribution Systems" were presented in an outstandingly meritorious paper by Wm. D. Hurst, Engineer of Water, Winnipeg, Man. The first part of Mr. Hurst's paper dealt with basic considerations and procedures in the design of a water works pipe system, and in the application of the Hardy Cross method of analyzing the system. After this he went into Winnipeg experiences in the retirement of cast-iron pipe which suffers graphitization from alkali soil attack in certain areas. Because of tuberculation inside and graphitization from the outside, 86.7 per cent of the original 4″pipe had been retired, but only 1.75 per cent of the 6″, and 6.3 per cent of the 8″. Securing an effective protective coating for the exterior of the pipe had not met with much success. In Winnipeg lead service pipe becomes granular and brittle, its life being 30 to 40 years. After 20 years copper tubing has shown no signs of failure. The meter maintenance program calls for service and checking of 1″ and larger meters every second year, while the smaller meters are removed only once in 7 years. The average cost of small meter repairs had been $9.82 per meter. Mr. Hurst advocated setting of low head loss velocity type master meters in district feeder mains to reveal flow conditions in the system more effectively. Meter repair cost studies had revealed the advantage of purchasing quality meters and parts.

In valving, Winnipeg installs not less than two gates at each intersection. All valves larger than 12-inch are set in concrete vaults, although Mr. Hurst recommends vaults for even smaller valves. Only stainless steel stems and gland and body bolts are now used, because of corrosive conditions.

Mr. Hurst is strong for accurate record keeping on all buried structures and units; and recommends the A.W.W.A. Recommended Practice for Distribution System Records —7G.1—1940.

In reply to questions, Mr. Hurst stated that reinforced concrete vaults under 3 ft. cover were employed. For 6″ valves a catch basin type of box is employed. Copper tubing had been of short life through cinder fills, and around livery stables ammonia entering the ground attacks the copper. A copper-to-lead joint shows rapid deterioration because of galvanic action.

The meeting closed with a 30 minute discussion of "Methods of Frost Control" under leadership of W. E. MacDonald of Ottawa, but we regret that our space has run out. However, it can be said that Canadians put their mains down deep and have less freeze-ups than are experienced in the States.

USE OF NOMOGRAPHIC CHARTS FOR FLOW IN PIPES, FULL AND PARTLY FULL

By H. M. GIFFT
Asst. Prof.
CORNELL UNIVERSITY
ITHACA, N. Y.

PRACTICALLY all flow problems can be solved by using either of two general equations, $V = CR^xS^y$ and $Q = AV$, or a combination of the two. Manning's formula, $V = \frac{1.486}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$, is probably more practical for an algebraic solution and is used extensively for open channel problems. The Hazen-Williams formula, $V = 1.318CR^{0.63}S^{0.54}$, is commonly used for flow in pipes under pressure. Because of the odd exponential functions, solution is ordinarily by alinement charts or logarithmic graphs.

The most common type of alinement chart is constructed for one friction coefficient and consists of parallel scales for the four variables Q, D, S and V, where Q = quantity, D = diameter of the pipe, S = slope of pipe, and V = velocity of flow. If the scales are located properly in relation to each other, solution may be had by a single alinement of a straightedge between any two unknowns to find the other two. Often two S scales are constructed on opposite sides of the line to provide for two possible friction factors. Such charts are found in most texts on water supply, sewerage, and hydraulics.

Sometimes it is desirable to solve problems for other values of C, in which case it is necessary to provide a pivot line along with the five variables Q, D, V, S and C. Most charts which appear in various hydraulics texts and handbooks include only four variables, and the fifth variable is obtained by solving the simple equation, $Q = AV$. All five variables, however, can be included, and by a proper arrangement of scales and pivot line it is possible to construct a chart to solve all full pipe flow problems.

Such a chart is illustrated in Fig. 1. The solution of ordinary problems by this chart is quite simple. Since there are five variables and only two independent equations, $Q = AV$ and $V = 1.318CR^{0.63}S^{0.54}$, three of the quantities must be known or assumed. An alinement of a straightedge is made between any

The Author

of the two variables on the *same* side of the pivot line. The straightedge is then pivoted to the third known quantity on the *other* side of the pivot line and the desired quantities read directly.

Solving Simple Pipe Flow Problems

Example I. Assume that a sewer to carry 10 c.f.s., when flowing full but not under pressure, is to be laid on a grade of 0.1 per cent. To determine the required diameter of pipe and the resulting velocity of flow if the C is assumed to be 100.

A straightedge is lined between C = 100 and S = 0.001 and the point of intersection with the pivot line is located. The straightedge is then pivoted about this point to Q = 10 c.f.s.; the diameter of 28.5 in. and the velocity of 2.25 ft. per sec. are read on the appropriate scales.

Example II. To determine the loss of head in a 24-in. water main carrying 20 cfs. if C = 120.

The straightedge is lined between Q = 20 cfs. and D = 24-in., and the point of intersection located on the pivot line. (The velocity is noted to be 6.5 ft. per sec.) The straightedge is then pivoted to C = 120 and the loss of head is 6.3 ft./1000.

Application of Chart to Equivalent Pipe Problems

Various other problems can be solved by a proper use of the chart. For example, in water distribution design it is sometimes desirable to determine the size of pipe which would be equivalent to several other pipes acting in parallel. If the pipes are all of the same length, any convenient point may be chosen on the pivot line and the discharges corresponding to the various sizes determined by successive alinements of the straightedge from the single point on the pivot line. The equivalent pipe will be found by alinement of the straightedge between the same point on the pivot line and a quantity equal to the summation of the individual quantities already determined.

Example III. To determine the size of a single pipe equivalent to 12-in., 10-in., and 8-in. pipes all of the same length and acting in parallel. Any point is assumed on the pivot line, say where $Q_1 = 40$ gpm. and D = 12-in. Then, holding this same pivot point, for D = 10-in., $Q_2 = 25$ gpm., and for D = 8-in., $Q_3 = 14$ gpm. Then for $Q = Q_1 + Q_2 + Q_3 = 79$ gpm., the equivalent pipe is 15.5 in. in diameter.

In case the given pipes are not of the same length, a total loss of head must be assumed and corrected to the loss of head per thousand feet for each of the pipes. From any single value of C and the computed three losses of head, three points are located on the pivot line. From these three points and the corresponding diameters, first Q_1, Q_2 and Q_3 are determined and the equivalent pipe is found as above.

Determination of Friction Coefficient

The resistance to flow in a water main may increase over a period of years. This change may be due to a change in the surface characteristics or a reduction in effective cross section due to deposition in the pipe. Thompson[1] has shown that flow characteristic of a length of main may be determined rather simply by a series of pressure measurements and a single measured flow from a hydrant. For a detailed description of methods of performing the test, the reader is referred to the original article.

Assume a certain quantity of water, Q, is drawn from a hydrant and the corresponding pressure heads determined at points on either side of and at the hydrant, these pressure heads being represented by H_1, H_2, and H_3. Then $\frac{H_1 - H_2}{L_1} = S_1$

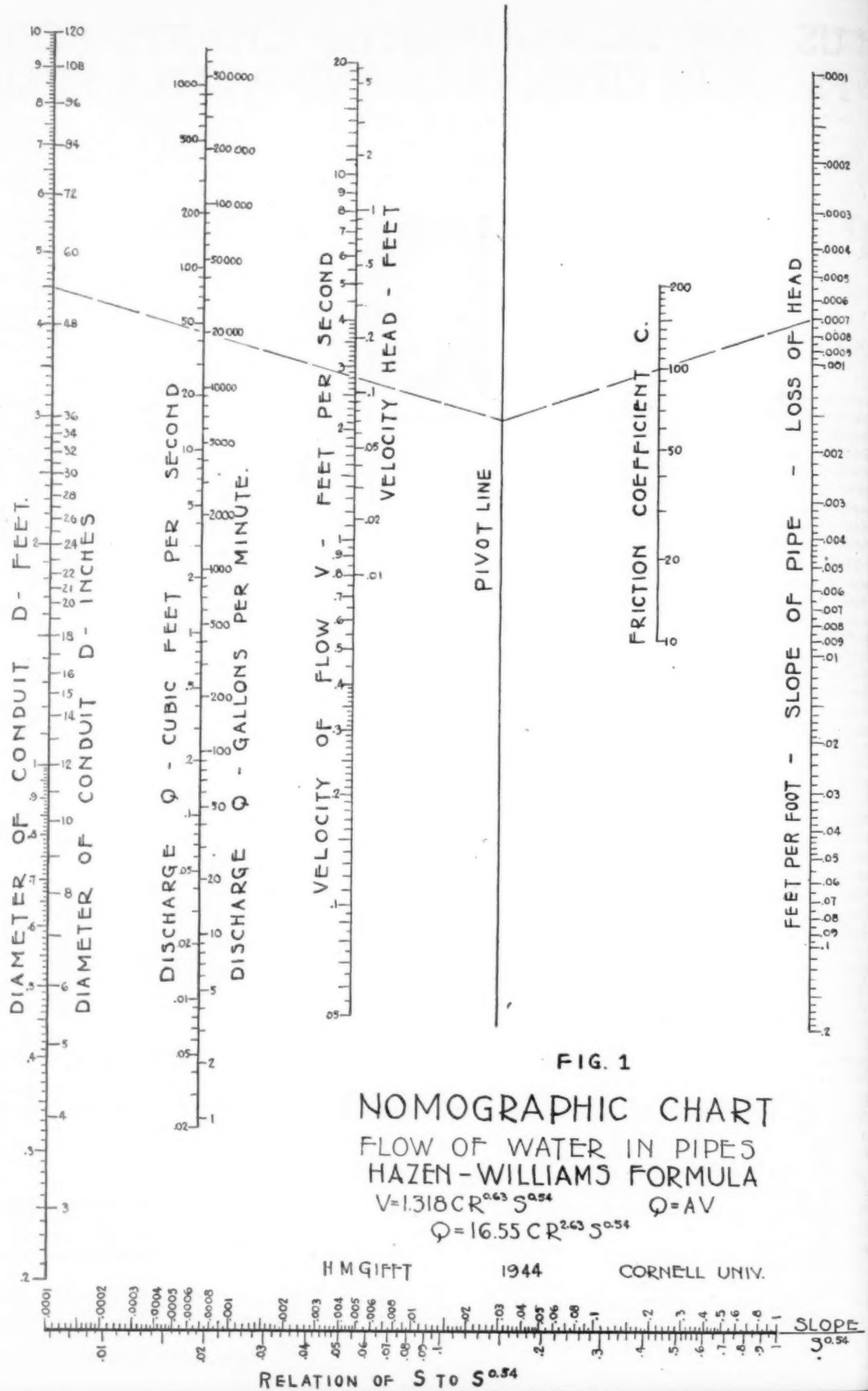

DIAMETER OF CONDUIT D - FEET.
DIAMETER OF CONDUIT D - INCHES
DISCHARGE Q - CUBIC FEET PER SECOND
DISCHARGE Q - GALLONS PER MINUTE.
VELOCITY OF FLOW V - FEET PER SECOND
VELOCITY HEAD - FEET
PIVOT LINE
FRICTION COEFFICIENT C.
FEET PER FOOT - SLOPE OF PIPE - LOSS OF HEAD
SLOPE
S^0.54
RELATION OF S TO S^0.54

FIG. 1

NOMOGRAPHIC CHART

FLOW OF WATER IN PIPES

HAZEN - WILLIAMS FORMULA

$V = 1.318 C R^{0.63} S^{0.54}$ $\quad Q = AV$

$Q = 16.55 C R^{2.63} S^{0.54}$

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represents the loss of head per foot for the length above the hydrant and $\frac{H_2-H_3}{L_2} = S_2$ represents the loss of head below the hydrant. (See Fig. 2)

Letting X represent the flow in the pipe in addition to the measured quantity, Q, then

$$\frac{X+Q}{A} = 1.318\ CR^{0.63}\ S_1^{0.54}$$

and

$$\frac{X}{A} = 1.318\ CR^{0.63}\ S_2^{0.54}$$

from which

$$Q = 1.318\ ACR^{0.63}\ (S_1^{0.54} - S_2^{0.54})$$

or

$$C = \frac{Q}{16.55\ D^{2.63}\ (S_1^{0.54} - S_2^{0.54})}$$

This equation can easily be solved by means of the chart and the special scale of S and $S^{0.54}$ at the bottom of Fig. 1. S_1 and S_2 are converted to $S_1^{0.54}$ and $S_2^{0.54}$ and the results subtracted to give $(S')^{0.54}$. Then $(S')^{0.54}$ is converted to S′ and this value is used on the nomographic chart to determine C.

Example IV. Pressure head measurements at the three points are $H_1 = 91.2$ ft., $H_2 = 83.6$ ft., and $H_3 = 80.7$ ft. when the quantity, Q, being drawn is 0.5 cfs. The size of the main is 12-in., $L_1 = 500$ ft. and $L_2 = 470$ ft.

$$\frac{H_1 - H_2}{L_1} = \frac{91.2 - 83.6}{500} = 0.0152 = S_1$$

and $S_1^{0.54}$ from the special scale is 0.105.

$$\frac{H_2 - H_3}{L_2} = \frac{83.6 - 80.7}{470} = 0.0063 = S_2$$

and $S_2^{0.54} = 0.063$. Then $S_1^{0.54} - S_2^{0.54} = 0.042$ and $S' = 0.0024$.

To determine C, line the straightedge between Q = 0.5 cfs. and D = 12-in., and locate the point of intersection on the pivot line. Then lining the straightedge between the point on the pivot line and S′ = .0024 on the loss of head scale, the intersection on the C scale is 29.

The increased resistance to flow may be shown in another way by determining the approximate effective diameter of the pipe. For the above conditions, the straightedge is lined between C = 100 and S′ = .0024 on the slope scale and a point of intersection located on the pivot line. Then pivoting about this line to Q = 0.5 cfs., the intersection on the D scale shows a diameter of 7.8 inches, indicating incrustations on the inside of the pipe approximately 2.1 inches in thickness.

To determine the approximate value of X (the flow in addition to the measured Q), the straightedge is lined between C = 100 and S = $\frac{H_2 - H_3}{L_2}$ = .0062 to a point on the pivot line. Then pivoting to the estimated effective diameter of pipe, 7.8 inches, as previously found, X is 0.9 cfs.

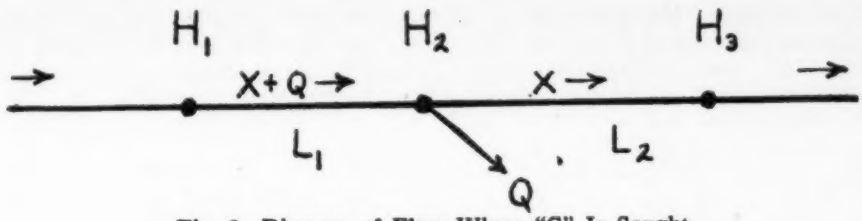


Fig. 2. Diagram of Flow Where "C" Is Sought

It should be remembered that the pressure heads must be determined with reference to the same datum plane. If the mains at the three points of pressure determination are not at the same elevation, the differences in elevation above the lowest point must be added to the pressure heads determined by the pressure gauge readings.

Application of Chart to Pipes Flowing Partly Full

Theoretically, when a pipe is flowing half full, the velocity V is equal to the velocity when flowing full, V_F, and the discharge Q is half of the full discharge Q_F. A line on the chart between $\frac{Q_F}{2}$ and V_F would also represent the discharge q, the diameter d, the slope s, and the velocity v, of a hypothetical pipe flowing full and having a slope of 1.5 times the slope S of the pipe being considered.

From $V = 1.318\ CR^{0.63}\ S^{0.54}$ and $Q = AV$, by eliminating R and A, we obtain

$$Q = 5.25\ \frac{V^{4.16}}{C^{3.16}\ S^{1.72}}$$

from which may be written

$$\frac{q}{Q_F} = \left(\frac{V}{V_F}\right)^{4.16} \left(\frac{s}{S}\right)^{1.72}$$

Inasmuch as s = 1.50 S then

$$\frac{q}{Q_F} = 0.5 \left(\frac{V}{V_F}\right)^{4.16}$$

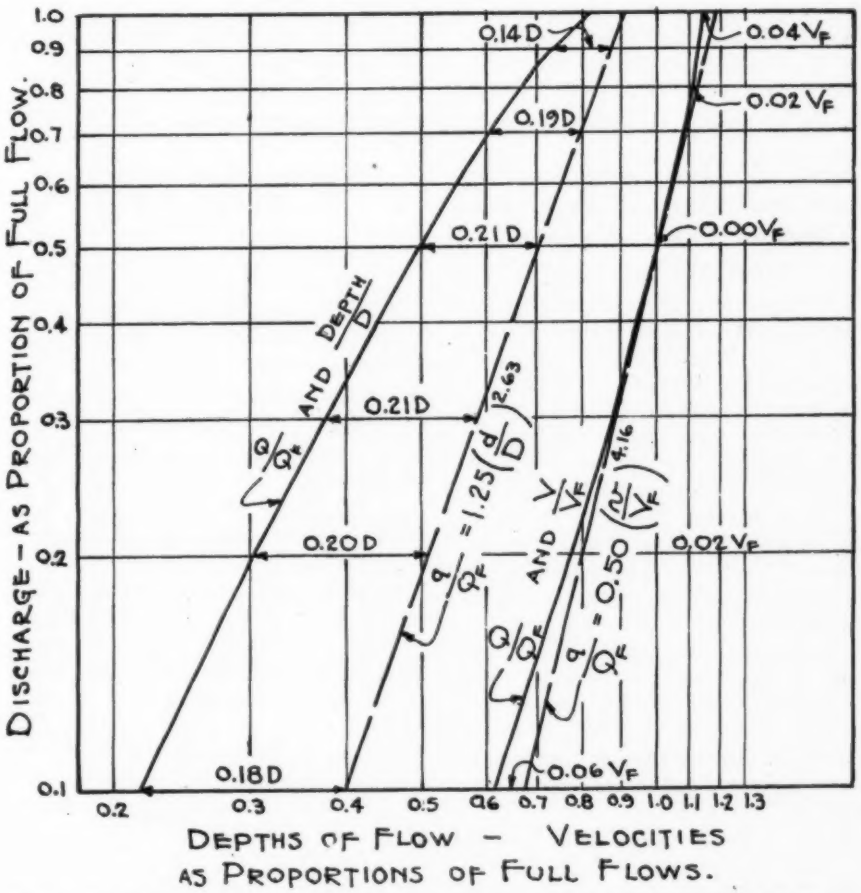


Fig. 3. Relation of Discharge to Depths of Flow and Velocity in Partly Full Pipes

(In terms of proportions of full pipes)

This equation, together with the computed relationship between partially full flows and corresponding velocities, is plotted in Fig. 3. Since the two curves are very close, the corresponding Q and V of the pipe flowing partly full at various depths would be practically equal to the q and v of a series of hypothetical pipes flowing full, and of $s = 1.50S$.

Also from $V = 1.318\ CR^{0.63}S^{0.54}$ and $Q = AV$, by eliminating V we may write $Q = 16.55CR^{2.63}S^{0.54}$.

$$\text{Then } \frac{q}{Q_F} = \left(\frac{d}{D}\right)^{2.63}\left(\frac{s}{S}\right)^{0.54}$$

and inasmuch as $s = 1.50S$,

$$\frac{q}{Q_F} = 1.25\left(\frac{d}{D}\right)^{2.63}$$

This equation, together with the computed relationships between partial flows and corresponding depths, was also plotted in Fig. 3. Over the range of values from $q = 0.1Q_F$, the d of the series of pipes flowing full is approximately 0.2D greater than the actual depth of the flow in the partly full pipe. Therefore, within these limits, approximate depths of flow can be determined by subtracting 0.2D from the indicated d of the hypothetical pipe. Three examples of the application of these equations follow.

Example V. To determine V and depth of flow when D = 30-in., C = 100, S = 0.0006, Q = 2.0 cfs.

From the intersection on the pivot line as determined by lining a straightedge between C = 100 and S = 0.0006, and pivoting to D = 30 in., $Q_F = 8.5$ cfs. and $V_F = 1.75$ ft. per sec. A line from $\frac{Q_F}{2} = 4.25$ to $V_F = 1.75$ intersects the pivot line again. Pivoting about this point to Q = 2.0 cfs., then V = 1.45 ft. per sec.

The depth of flow is 0.20 less than the intercept of 1.33 on the diameter scale. Depth = 1.33 — 0.50 = 0.83 ft. Using the same pivot point, other corresponding values of Q, V, and depth of flow can be obtained.

A simpler solution may be obtained by making the original alinement between C = 100 and $s = 1.5S = 1.50(.0006) = .0009$ to determine the pivot point directly. Since this method simplifies the solution and the calculation of 1.5S can be done mentally, this method is preferable.

Example VI. To determine D and minimum slope S, such that V = 1.5 ft. per sec. at minimum flow when $Q_F = 14$ cfs., C = 90, $Q_{min} = 2.1$ cfs.

A straightedge is lined between Q = 2.1 and V = 1.5 to determine a pivot point. Pivoting about this point to $\frac{Q_F}{2} = 7.0$, then $V_F = 1.97$. A straightedge between this $V_F = 1.97$ and $Q_F = 14.0$ yields D = 3.0 ft., and determines a new pivot point. Pivoting about this second point to C = 90, then S = .0073.

Example VII. To determine the slope when D = 6.0 ft., C = 110, Q = 250 cfs., V = 12 ft. per sec.

The straightedge is lined between Q = 250 and V = 12 to locate a pivot point. Pivoting about this point to $d = \frac{D}{2} + 0.2D = 4.2$ ft. on the diameter scale, then $q = 150 = \frac{Q_F}{2}$ and v = 10.3 ft. per sec. = V_F. Then pivoting about $V_F = 10.3$ to $Q_F = 2 \times 150 = 300$, D = 6.0 ft. (as given) and a new point is determined. Finally pivoting to C = 110, S is found to be .0048.

All the above problems except example IV may be performed easily on the common four scale alinement chart[2] having the variables Q, D, S, and V, or on a comparable logarithmic graph, but a separate chart or graph is necessary for each value of the friction coefficient, whereas this one nomograph will solve all.

References

[1]Thompson, R. E., Resistance Coefficient Calculation from Incremental Flow Measurement. Jour. AWWA. 36, 163, Feb., 1944.

[2]Gifft, H. M., Nomographic Chart for Flow in Pipes Partly Full. Civil Engineering 14, 115. March 1944.

Court Holds Operation of Sewage Plant a Corporate Rather Than Governmental Function

An important decision of the Supreme Court of New Mexico holds the City of Santa Fe liable for the drowning of a 10-year-old girl in one of the city's sewage treatment plant tanks. The decision of the higher court reverses the decision of the lower court which had held the city not liable for the death of the little girl because operation and maintenance of treatment plants fell under the classification of a governmental function.

The higher court pointed out negligence in operating the sewage plant of Santa Fe, and the inadequate fencing around the plant. Thus an attractive hazard was permitted to exist through negligence in maintenance.

To us this decision is indicative of what's to be expected in the future. "Discharge of a governmental function" ceases to be a tenable basis for avoiding damage suits.

Sludge Gas Engines for 31,400 B.H.P.

Represents New York's Evaluation of Byproduct Power Development

At the various sewage treatment plants of New York City is to be found an existing or planned use of sludge gas engines to the extent of 31,400 BHP. capacity.

In the direction of power development from the byproduct gases at sewage works the following New York City record is impressive, since New York's Dept. of Public Works did not proceed with such a program before ample demonstration of the economics of such power production afforded by the 1936 Coney Island installation.

Plant	Year Installed	No. Engines	Total B.H.P.
Coney Island	1936	3	900
Tallmans Island	1939	8	3,580
Bowery Bay	1941	2	1,600
Coney Island	1942	3	2,700
Jamaica	1943	3	4,320
26th Ward (under contract)		3	3,900
Owl's Head (Designed)		5	5,000
Newtown Creek (Designed)		4	5,800
Hunt's Point (Designed)		4	3,600
Total		35	31,400

Philadelphia Sets Up Sewer Rental Charges to Finance $42,000,000 Disposal Program

The proposed $42,000,000 sewage disposal program for Philadelphia will be financed through sewer rental charges unless the recently passed ordinance fails to stand-up in court tests.

The new ordinance provides a sliding scale of notes for sewer service which range from a charge amounting to 100 per cent of the water bill to the smaller domestic sewers to 50 per cent of the larger metered customers including commercial and industrial users.

Out of the new sewer service charges it is proposed to retire the existing sewer debt amounting to $55,000,000 while also financing the proposed $42,000,000 disposal program. This retirement of over accumulated long-time debt for current sewer service charges is, we believe, a new venture in sewerage financing. Developments will be watched with some interest.

WHAT YOU SHOULD KNOW ABOUT YOUR STEEL WATER TANKS

With Especial Reference to Cleaning, Painting and Cathodic Protection

By JOHN M. PERRYMAN
Engineer
R. D. COLE MFG. CO.
NEWNAN, GA.

STEEL water tanks and towers should receive careful annual inspections and not suffer from neglect. Some estimates of cost, intended to provide ideas of the amounts involved to properly protect water tanks of various sizes, are given in this article.

Leading designers, fabricators and erectors of steel water tanks are in position to offer inspection service and competent advice as to necessary work that may be required to maintain or place tanks in the best of condition. This service will usually cost from $100.00 to $150.00, depending upon the location.

Paint has been and still is the proven method for the protection of steel, although, through research and experience, other methods are being used. Therefore, some are mentioned for your consideration.

Even the best paints will not adhere to rusty steel without the steel having been properly cleaned of all loose rust, grease and old loose paint. Thorough wire brushing is all that is really necessary, although in badly corroded structures, more severe methods may be required, such as sand-blasting. See specifications at end of this article.

The ideal time to clean, paint and repair is during the late spring and the early fall months, and never when temperatures are likely to be less than 50 degrees, and the ideal is from 60 to 70 degrees.

Good Paint Is Good Economy

The use of good paint is good economy. Since labor is the governing factor in the cost of painting, amounting to approximately 80 per cent of the total cost, the use of the better grades of paint adds little to the final cost.

The American Water Works Association and some insurance underwriters have published specifications for proper methods of tank cleaning and paints that are satisfactory. Therefore, it is suggested that you communicate with them or with the manufacturer of your elevated tank,

The Author

in order that you may secure the best available information before proceeding with the cleaning and painting of your water tanks.

A fact to remember is, to "repair" before painting, so it is desirable that you secure the advice of experts before proceeding with your painting. When experts are mentioned, do not be misled by false or misleading statements. Remember the loads involved in water tanks of the elevated type are highly concentrated—and the advice of so-called "steeple-jacks" that are not professional engineers, cannot therefore be relied upon, as usually they do not have knowledge of the stresses or the methods of calculating stresses to advise you fully as to the strength or weakness in a steel tank. It is suggested, therefore, that you ask for credentials or other evidence as to one's ability to pass judgment on tank details, as this is highly important.

Furthermore, before entering into a contract, be certain that all work to be done has been agreed upon in writing, and that no hidden clauses are in the contract which entitles the person or persons doing the repair work to proceed with additional repairs or replacements without written advice and predetermination of cost.

Estimating Paint Requirements

Now let us consider quantity of paint involved to properly paint your tank. Chart No. 1 shown gives the average quantity of paint required, and I believe that this is fully self-explanatory. This chart is for your guidance and should take care of all popular sizes of elevated steel water tanks.

Paints of the highest quality can currently be procured at about the following prices:

Red lead—$4.50 per gallon.
Black interior water tank paints—$3.50 per gallon.
Aluminum and other high grade exterior paints for steel structures at approximately $4.00 per gallon.

Sample Estimate

You may refer to Chart No. 1 and secure therefrom the amount of paint required for your tank, and then total the approximate cost as illustrated:

Take for example 100,000 gallon elevated tank together with a steel tower 100 feet high and a 3-foot diameter steel riser and calculate as follows:

1.—Inside red lead (15 gals.) @ $4.50	$ 67.50
2.—Inside black paint (15 gals.) @ $3.50	52.50
3.—Outside red lead (5 gals.) @ $4.40	22.50
4.—Outside aluminum (40 gals.) @ $4.00	160.00
Total for materials	$302.50
Add for labor and incidental cost, four times the cost of paint	1210.00
Total cost for doing a nominal amount of wire brushing, both inside and outside, replacing manhole gaskets, and stopping any small leaks (not to exceed 10), total cost	$1512.50

CHART NO. 1

Gallons of Paint Required Based on 100-ft. Towers

	50,000 Gallons	75,000 Gallons	100,000 Gallons	150,000 Gallons	250,000 Gallons	500,000 Gallons
First Coat Inside	8	10	12	15	25	50
First Coat Outside	12	14	17	22	35	70
Second Coat Outside	12	14	17	22	35	70
*Riser, per coat	3	3	3	3	3	3

Note: The 3 gallon requirement is for 3' diameter risers. For 4' diameter riser, add 3 gallons; for 5' riser, add 6 gallons per coat.

When Using Cathodic Protection

In lieu of painting the tank complete on the inside, you may calculate the approximate cost of painting the underside of the roof and top ring on the inside of the tank and the outside of the tank to be painted with two coats of paint and for the inside using Cathodic Protection. The cost will be about as follows:

Inside red lead (5 gals.) @ $4.40	$ 22.50
Inside black paint (5 gals.) @ $3.50	17.50
Four times materials for labor	160.00
Scaffold	50.00
Cathodic unit installed (see Chart No. 2)	600.00
Total	$850.00

And to the above you must add the cost of the outside painting; (see first tabulation—items 3 and 4.)

Paints for outside	$ 182.50
Four times material for labor	730.00
Total cost of painting the outside	$ 912.50
Cost of painting outside of tank and tower, painting underside of roof and installing Cathodic Protection on inside	850.00
Total cost	$1762.50

Bituminous Enamel Interior Coating

Another method of protecting the inside, is with the use of one coat of Bitumastic Priming Solution and one coat of Bitumastic Enamel on the inside of the riser, the bottom and shell of the tank and painting the underside of the roof two coats of Bitumastic Solution. The approximate cost of doing this work is about $1350.00 for applying Bitumastic Enamel on the inside and the cost of painting the outside of the tank—$912.50; giving a total of $2262.50.

From the above illustrations and using Charts No. 1 and No. 2, you can approximate the cost of cleaning and painting your tank; applying Cathodic Protection to the inside or using the Bitumastic Enamel.

In using the above estimates, remember excessive cleaning, repairs and replacements *are not included* in the estimates of cost outlined, nor does the information given outline the advantages or peculiarities of any of the principal methods of giving protection to your tank; nor do they include estimates of life expectancy or protection, upkeep of operating devices and operating cost of the electrical protective devices.

CHART NO. 2

Cathodic Protective Units

The approximate cost of Cathodic Protection, not including cost of cleaning the inside of tank, nor painting the underside of the roof and top shell ring:

50,000 gallon tank	$ 500.00
100,000 gallon tank	600.00
250,000 gallon tank	800.00
500,000 gallon tank	1000.00

Cost of painting underside of roof and top shell ring:

50,000 gallon tank	$ 225.00
100,000 gallon tank	250.00
250,000 gallon tank	400.00
500,000 gallon tank	600.00

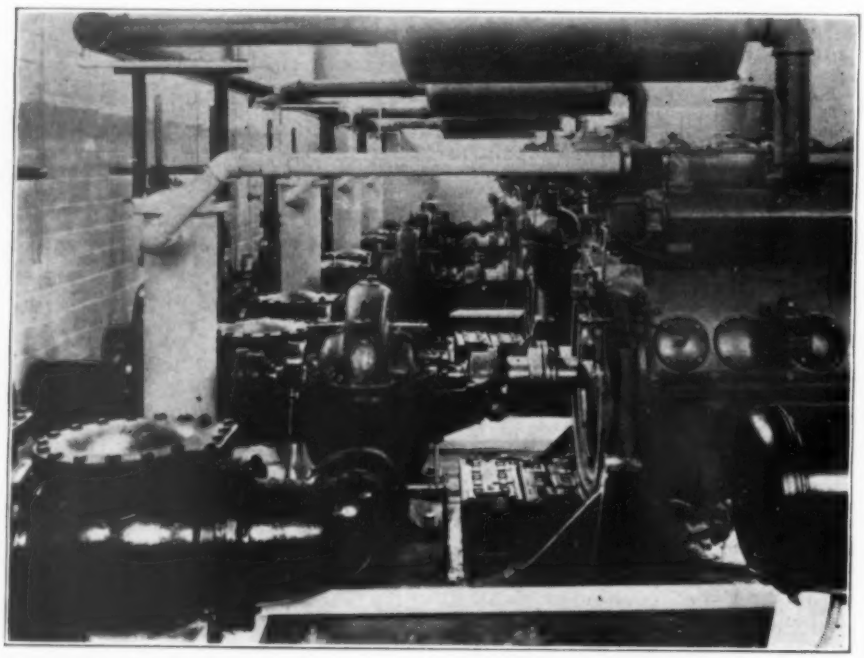
Approximate cost applying one coat Bitumastic Solution and one coat Bitumastic Enamel to riser, bottom and shell and two coats Bitumastic Solution underside of roof:

50,000 gallon tank—3′ riser	$1200.00
100,000 gallon tank—3′ riser	1350.00
250,000 gallon tank—4′ riser	2300.00
500,000 gallon tank—5′ riser	3500.00

Cleaning, Repair and Painting Specifications

For "A Pattern for Specifications," suggested for use in tank cleaning and repainting projects, the reader is referred to the specimen specifications given on page 77 of the 1944 Reference and Data Number of WATER WORKS AND SEWERAGE—June 1944. Or, a copy of these "Pattern Specifications" can be had by addressing the author.

New London's New Pumping Station



New London, Conn., is proud of its new pumping station, which incorporates a design departure in the elimination of gears between the four Murphy Diesel Engines connected directly to the shafts of four Morris Double Suction Centrifugals of 1750 gpm. capacity each against 125 ft. dynamic head.

The Morris pump impellers were specially designed to permit the use of direct shaft drive from the Diesel engines, without the customary intermediate gears.

When operating at a speed of 1140 rpm. the pumps have delivery 1000 gpm. into the New London system at the remarkably low fuel cost of $4.00 per million gallons.

$12,000,000 Voted by Portland, Ore., for Postwar Sewerage Project

On May 19th the voters of Portland, Oregon, by a majority of better than two to one approved the City Council proposal to issue bonds for sewerage improvements in the impressive amount of $12,000,000. These improvements involve construction of an adequate system of interceptor sewers, revamping or replacing and extending existing sewers and the construction of necessary pumping stations and modern sewerage treatment facilities. At the same time the voters authorized an amendment to the City of Portland charter exempting such bond issue from the legal debt limitations in the city charter and authorized special levies to pay the costs.

In addition to the twelve million for sewerage betterments $5,000,000 was voted at the rate of $1,000,000 per year for better school buildings; $3,000,000 for dock and harbor improvements and for county road construction, $4,000,000, making a grand total for postwar projects of $24,000,000 indicating how postwar minded Portland's citizens are. Next to the school issue the sewerage issue received the largest majority vote.

KEEPING FILTERS CLEAN WITH CHLORINE

By H. W. POSTON
Asst. Supt.
DEPT. OF WATER AND ELECTRICITY
OTTUMWA, IOWA

THERE has been considerable writing about mud-balls, filter cracks, and incrustation of sand in rapid gravity sand filters. Surface wash and high rate wash have been developed. Chemical means for cleaning filter sand include acid, alkali or sulphur dioxide treatment. These methods have all been used for the purpose of keeping foreign material from accumulating on the sand grains and remaining in the filters.

The Ottumwa water supply, taken from the Des Moines River, is treated with chlorine, lime, soda ash, iron sulphate, and carbon dioxide prior to filtration. The settled water going to the filters has a turbidity of between 2 and 10 ppm., most of which is due to precipitation of calcium carbonate in connection with the softening process. The applied water alkalinity is between 30 and 60 ppm., with 10 to 30 ppm. being in the normal carbonate form. During the past two years the pH of our filtered water has been maintained near pH 9.0.

An effective, simple and inexpensive procedure for elimination of foreign material from the filters by means of chlorine application has been developed at the Ottumwa Water Works. A strong solution of chlorine is applied regularly at times when the filters are washed. It is allowed to remain in the filter for a period of approximately twelve hours. (Plant is operated twelve hours per day.) The chlorine solution, when allowed to remain in the filter, dissolves deposits on the sand, kills any bacteria in the filter, and in general keeps the filter free from foreign material which might cause cracks and mud-balls.

This system for keeping the filters clean has been used for the past six to seven years. No trouble has been experienced with mud-balls, filter cracks, or incrustation of the filter sand during this time. The ease of application of this treatment and its economy not only in operation, but also installation, make it, in our opinion, a most excellent method for keeping filters clean.

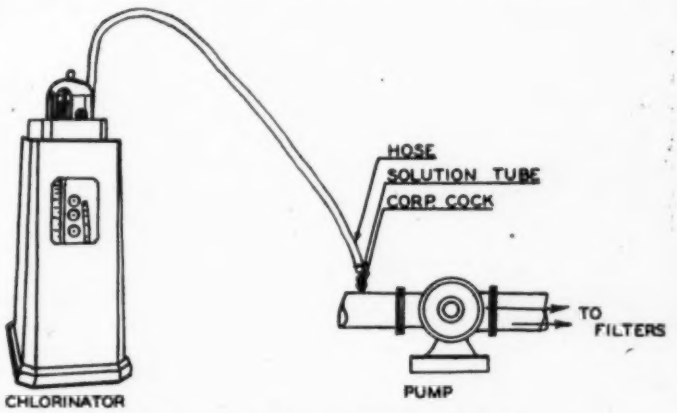
Procedure

For application of chlorine to the filters, which is done each time the filters are washed, the raw water chlorinator is used. Being situated near the wash water pump, no long solution lines are necessary. The only equipment needed was a length of chlorine solution hose, corporation cock, and a chlorine solution tube.

A tap was made in the suction pipe to the wash water pump. The solution tube along with the corporation cock was installed, and connection was made from the chlorinator to the corporation cock with the chlorine solution hose. In operation the set-up is as shown in the accompanying sketch.

Our chlorinator has a capacity of 2100 lbs. per day. In chlorination of the filter it is set to deliver at the rate of 1100 lbs. per 24 hours, which will feed about 17 ppm. at maximum wash water rate. The gradual reduction of wash water at the end of the washing period allows the chlorine concentration to be increased to any residual desired.

During an average filter wash, the chlorine residuals of the wash water are as follows: At start, 27 ppm., wash at maximum, 17 ppm., and at end of wash, 40 ppm. The residual on top of the filters is 19 ppm. at the end of the washing period. After standing over night the filters will still carry a chlorine residual of 13 ppm.



Chlorinator Hook-up to Filter Wash Line

Results

Our filters have been in operation since 1933. The sand has never been removed and there is no sign of mud-balls, lime incrustation, or filter cracks.

During the past year our filters were washed after 108 hours operation, on the average. Each filter is washed between ten and twelve minutes. The filter breaks uniformly over the whole bed at the start of the back wash.

There is no evidence to show that the strong chlorine solution has caused any deterioration of pump, pipe line, or filter under drains. The best reason we have for believing the chlorine has had no deleterious effect is its long period of use with no outward sign of damage resulting. However, at Ottumwa we have no brass in our under drain system which consists of concrete slab false bottoms fed through drilled 8 in. C. I. pipes beneath the distribution slabs.

WATER AND SEWAGE PATENTS

(OF RECENT ISSUE)

WATER PATENTS

LIQUID LEVEL INDICATOR. Edward A. Korevec (½ to Leo M. Herkert). U. S. 2,345,054. Mar. 28. A device with an endless graduated tape, readable through a window, to denote level of liquid in an adjacent container.

PIPETTE WASHING APPARATUS. Elmer E. Meyers and Earl E. Boehm. U. S. 2,345,284. Mar. 28. A device for washing pipettes.

PURIFICATION OF WATER. Hubert L. Olin. U. S. 2,345,827. April 4. A process of clarifying natural raw water by separately dispersing therein a slurry of unflocculated sodium mentonite and ionizable material, and permitting the bentonite to react with ionizable substances in the raw water or the added material to form hydrous flocs.

CLEANER WITH DOUBLE WASH WATER BOX. Charles E. Frazer. U. S. 2,346,215. April 11. A traveling cleaner for a filter bed with a means to shut off filtering action in the section of the filter being cleaned during the process.

FILTER CLEANER WITH BED SETTLING CHAMBER. Charles E. Fraser. U. S. 2,346,216. April 11. A variation in design of U. S. Patent 2,346,215.

DEEP WELL SCREEN. Howard O. Williams and Albert A. Jens (to Edward E. Johnson, Inc.) U. S. 2,346,885. April 18. A different design for deep well screens.

VALVE. Ralph G. Carlson (to Crane Co.). U. S. 2,346,904. April 18. A packless valve with ported seat and closure member for controlling opening of said ports.

WATER SOFTENING MATERIAL AND MANUFACTURE THEREOF. Sven Dahl-Rode. U. S. 2,346,909. April 18. A method of making a water softening material which comprises treating coffee particles with sodium hydroxide solution in the presence of metallic aluminum and then treating the coffee particles with an alkali metal silicate solution.

CIRCULATING AND FILTERING SYSTEM FOR SWIMMING POOLS AND THE LIKE. Richard D. Evans. U. S. 2,347,092. April 18.

WATER SOFTENING APPARATUS. Lynn G. Lindsay. U. S. 2,347,201. April 25. A design for a pressure type softener utilizing a zeolite type of softening material requiring regeneration.

FLUID FLOW INDICATOR. Richard Fife Walker (to Walker, Crosweller & Co., Ltd., Cheltenham, England). U. S. 2,347,304. April 25. A fluid flow indicator for positioning in a fluid line. U. S. 2,347,306. April 25. A variation of above.

METHOD AND APPARATUS FOR TREATING LIQUID. William Brewster Guerney (to Permutit Co.). A device for treating liquid in lower coagulating zone and flowing mixture of liquid, treating agent, and sludge upward into a precipitating zone.

LIQUID LEVEL INDICATING SYSTEM FOR USE IN TREATING WELLS. Ormand E. Barstow (to Dow Chemical Corp.). U. S. 2,347,589. April 25. An apparatus for introducing into a well an electrically conducting liquid and measuring its level therein.

APPARATUS FOR TREATING WELLS. Paul G. Shelley (to Dow Chemical Corp.). U. S. 2,347,615. April 25. A variation of U. S. 2,347,589.

LIQUID-LEVEL MEASURING APPARATUS. Raymond E. Sprenkle (to Bailey Meter Co.) U. S. 2,347,637. April 25. A water level indicator including a mercury U-tube one leg of which is covered with cold water and the other leg having water above it varying as the height of the level to be measured. Variations in height of liquid level are indicated by means dependent on the variation in the density of the variable column of liquid.

ROTARY PUMP. Elbert Fowler. U. S. 2,347,944. May 2. A rotary pump of sliding vane type.

LIQUID TREATMENT. Walter H. Green (to Infilco). U. S. 2,348,122. May 2. A method and apparatus for split treatment of water to cause precipitation of solid particles and use of separated slurry in first step of split treatment. U. S. 2,348,123. Walter H. Green and J. R. Barrington (to Infilco). A combination treating basin, with rotary distributor at bottom, up flow through precipitated slurry and withdrawal from surface. U. S. 2,348,124. Walter H. Green (to Infilco). Water treatment and coagulation chamber with mixing devices, up flow and discharge to adjacent sedimentation basin.

CENTRIFUGAL PUMP. U. S. 2,348,246. Ralph H. Dixon. May 9. A self-priming centrifugal pump.

SEWAGE PATENTS

MECHANICAL AERATOR. Augustus C. Durdin III (24 per cent to Lewis H. Durdin and 52 per cent to Augustus C. Durdin, Jr.). U. S. 2,346,366. April 11. A mechanical aerator comprised of a tube for fluid flow flared at its upper outlet end, with a reaction cone mounted in the flared outlet but spaced therefrom and a fluid propulsion vane below the cone.

AERATION APPARATUS. Augustus C. Durdin III (24 percent to Lewis H. Durdin and 52 per cent to Augustus C. Durdin, Jr.). U. S. 2,346,367. April 11. An aeration apparatus utilizing an air conduit and porous diffusers.

CLARIFICATION OF WHITE WATER BY FROTH FLOTATION. Robert Ben Booth (to American Cyanamid Co.). U. S. 2,347,147. April 18. A method of clarifying paper mill waste waters and recovering the filler and fiber therefrom by subjecting said wastes to a froth flotation utilizing a promoter of higher fatty acids or the like.

SEWAGE TREATMENT. Walter H. Green (to Infilco) U. S. 2,348,125. May 2. Apparatus consisting of clarifier, and sludge digester adjacent to one another, the former containing mechanical equipment. U. S. 2,348,126. Sewage treatment apparatus comprising clarification chamber, biological treating chamber, sludge digester, and appurtenances to each.

SEWAGE SAMPLER. H. W. Gillard and S. L. Adelson (to Infilco, Inc.). U. S. 2,348,806. May 16. An automatic sampling device with refrigerated storage for sample during collection period.

SEWAGE PURIFICATION AND TREATMENT. August Schreiber (vested in Alien Property Custodian). U. S. 2,348,854. May 16. A biological treatment comprising downward percolation of sewage through solid particles. Percolating media particles are withdrawn from bottom of tank and screened to remove part of the sludge deposited thereon. Withdrawn particles are thereafter returned to surface of the "filter" within the tank, along with fresh sewage while mixing air with the sewage and solid particles.

The pot of gold DOES *exist*

Drenching rains bring a golden cavalcade of prosperity to humanity, for water is life's most vital substance. Nature supplies the element. Man conditions its utility. To capture the free waters from the heavens, impound them, purify, pump and pipe to homes, institutions and industries, is the responsibility of our able Public Utilities —a tremendous contribution to America's welfare. To accurately meter water is the responsibility of *Pittsburgh-National Meters*—and this, too, is a vital economic function; for water is not delivered free. Charges for it should be equitably apportioned. From the fairness of dependable metering, satisfied consumers and good public relations are created. That is a *pot of gold* not to be overlooked.

PITTSBURGH-NATIONAL METERS

—charged with the responsibility of accurately measuring water

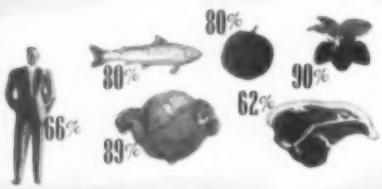
Interesting Facts About WATER

A CHEMICAL MYSTERY

Water is H_2O—two parts hydrogen and one part oxygen. As separate gases they are highly explosive. By some mystery of nature, H_2O combines atoms to make water.

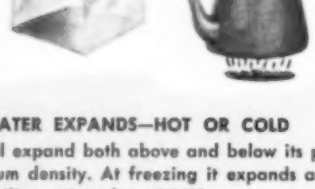
HOW MUCH OF EARTH'S SURFACE IS WATER?

About 16,000,000 tons of water fall on the earth every second. The earth's surface is nearly three-fourths water. If leveled off it would be covered with water to a depth of two miles.



WATER IN FOODSTUFFS

All foodstuffs contain water; some as high as 95%. The average human body contains about twelve gallons of water, comprising about 66% of the body. The brain contains about 85% water.



WATER EXPANDS—HOT OR COLD

Water will expand both above and below its point of maximum density. At freezing it expands about 9%; at boiling point, about 164%.

HOW MANY METERS?

Tens of millions of water meters have been produced since metering was introduced by Utilities several decades ago. Metering is the fairest and most equitable method of computing water usage.

—there's a PITTSBURGH-NATIONAL METER *for every kind of service*

ONLY Pittsburgh-National offers a choice of types as well as a complete range of sizes in water meters. Whether at war or peace, purchasers always receive top measurement value. Today, thanks to the most progressive as well as extensive engineering and research facilities in the Industry, these meters are still "built right to measure right." There has been no war-time change or sacrifice in the proven inner working mechanisms. You can now, as always, buy any Pittsburgh-National Meter with full confidence in its ability to measure accurately and serve faithfully.

WE STILL SAY—don't replace when you can repair. Our country's interests come first. An intelligent program of meter reconditioning and maintenance can, in many cases, largely supplant the need for new meters. All Pittsburgh-National Meters are economical to repair, and replacement part stocks are adequate.

PITTSBURGH-NATIONAL *Water Meters*

PITTSBURGH EQUITABLE METER COMPANY

MERCO NORDSTROM VALVE COMPANY

Main Offices: Pittsburgh 8, Penna.

NATIONAL METER DIVISION, BROOKLYN, N. Y.

Atlanta, Boston, Brooklyn, Buffalo, Chicago, Columbia, Houston, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco, Seattle, Tulsa.

COLLOIDAL SILICA AS AN AID TO FLOC FORMATION

By HAROLD R. HAY
Chemical Department
PHILADELPHIA QUARTZ CO.

PART I—Jar Test Evaluation and Factors in Plant Use

WHEN a new chemical finds rapidly increasing favor for coagulation despite the fact that its application is not quite so simple as that of most coagulants, there is reason to determine the basis of its recognition. Sodium silicate is that chemical being accepted because of the striking effect upon floc formation through coagulant aids derived from it. Numerous articles have been published indicating superior results on waters of widely varying characteristics. Sewerage treatment has also been improved with silicate preparations. A review of this literature, together with information on the properties of sodium silicates, has been presented elsewhere.[1]

In brief, it may be said that silica coagulant aids frequently produce large, dense and tough flocs which cannot be obtained with regular coagulants alone. Baylis[2] designated the floc size obtainable with silica as "immense." It has been shown in one type of water that colloidal silica gave rapid formation and settling of the floc when all other known coagulants had proved inadequate. Increased plant capacity through higher flow rates, longer filter runs, lower chemical costs and better softening results have been observed. Substantial reduction in the cost of new plant construction has been reported. Particularly outstanding benefits have been contributed to lime softening. On the other hand, in some waters the silica treatments do not give results of sufficient merit to warrant adoption.

An accurate evaluation of silicate preparations may readily be obtained from jar tests, particularly if a mechanical device for agitation is provided. These machines are rapidly becoming an essential piece of laboratory equipment at coagulation plants and are particularly useful in determining chemical treatment for supplies of changeable quality. Suggestions for the laboratory preparation and testing of silica coagulant aids were first made by Baylis[2] in *Water Works and Sewerage*. In most cases where silica has been adopted the values were first determined by jar tests, after which successful plant runs were made.

The Author

It has been common practice to use silica coagulant aids only during that part of the year when it is difficult to obtain good flocculation. In known cases this periodic requirement arises from low water temperatures in winter, the necessity of removing iron developed by bacteria during summer months, or the need to change the source of water supply due to seasonal fluctuations in availability. Heavy rains and floods sometimes are occasions for the use of silica. In one area the periods of difficult coagulation appear to be associated with the velocity and direction of the wind which affects the turbidity of the reservoir. Variations in pH or the appearance of special types of wastes may produce conditions not easily corrected with the usual coagulants. The silicate preparations should be investigated during such extremes as well as during the more normal periods. When water characteristics are uniform, the evaluation can be concluded more promptly, and if the coagulant aid is required its use would then continue throughout the year.

Types of Silicate Preparations

Several methods for converting sodium silicate into a useful coagulant aid have been developed and are in current use. The important types with differentiating characteristics are given in Table I. In all cases the silicate is reacted with a second chemical. No substantial difference has been found in the effectiveness of the coagulant aids prepared by partial neutralization of sodium silicate with any of the various acids, acid forming materials or ammonium salts. Differences are obtained, however, between the two types involving metallic salts. This apparently is associated with the alkalinity of the preparation prior to dilution in the water to be treated. It is to be expected that the colloidal particles formed in the reactions will have a greater negative charge in alkaline solutions, and a positive charge (or in the case of silica, a decreased negative charge) when acidic. It is advisable, therefore, to investigate the three silicate combinations before reaching conclusions on the value of sodium silicates for any given coagulation problem.

TABLE I
Differentiating Characteristics of Sodium Silicate Coagulant Aids

Type	Sodium Silicate Reacted with	Method of Preparation	Alkalinity Reduction	Stability of Preparation	Aging Requirements	Usual Manner of Use
Baylis Sol	Acid or acid-forming material	Batch*	Partial	Great	Depends on use	Added before the coagulant
N-Sol A	Ammonium salts	Batch*	None	Great	Depends on use	Added before the coagulant
Graf-Schworm Coagulant	Alum or iron salts	Continuous	Complete	Not required	None	Added as complete treatment
N-Sol B	Alum or iron salts	Batch*	Partial	Great	Depends on use	Added; then followed by more coagulant

*Continuous preparation now in process of development.

Nomenclature

With sodium silicates and silica entering into water treatment reports in various manners and for different purposes, it is important to accurately identify the form in expressing dosages. Sodium silicates are manufactured in various compositions and at different concentrations. Only products of known approximate analysis should be used for any purpose connected with a scientific water treatment.

Inasmuch as manufacturers differentiate between soluble silicates in terms of the ratio between the alkali and silica contents and concentrations of definite Baumé density, these terms should be used to express the dosage of a sodium silicate applied as such. Where a brand name exists which has long been associated in the literature with a specific composition and is not to be confused with other silicate solutions, the use of such name may be adequate for general purposes. A mere statement of "25.0 ppm. sodium silicate," however, means very little and would not permit comparative studies by other investigators.

In coagulation, the formula $-SiO_2-$ is being adopted to differentiate the specially prepared silica from naturally occurring or chemically bound SiO_2 reported in water and silicate analyses. The symbol indicates the presence of a negative charge. These distinctions will avoid confusion. Examples of clear intent are: for *naturally occurring* or *combined* silica, 14.8 ppm. SiO_2; for *coagulation*, 3.5 ppm. $-SiO_2-$; for *corrosion control*, 25.0 ppm. sodium silicate of ratio 1:3.2 and 41° Baumé or 25.0 ppm. N brand silicate of soda.

Recommended Grade of Sodium Silicate

Inasmuch as many as fifty different grades of sodium silicates are available from a single manufacturer, it is apparent that specifications are required to select the most economical one for a given purpose. Discussing the purchase of large quantities of sodium silicate for coagulation use at St. Louis, Mo., Graf[3] states: "Our specifications call for not less than 28.7 per cent of silica, not less than 8.6 per cent of sodium oxide, and a specific gravity of not less than 40.6° Baumé. This grade yields the most silica per dollar cost. Sodium silicate delivered to our switch cost $12.13 a ton."

This price of approximately 60 cents per hundred pounds applied to tank car quantities of 8,000 gallons each in a city where the silicate is manufactured. In small quantities and at points considerably distant from manufacturing sites the cost will be proportionately higher and may reach several times the quoted figure. Baylis[2] similarly specifies the silicate to be used in his preparation. "These instructions apply only to the grade sodium silicate which was used; that is, 41 to 42 Baumé material having a Na_2O-SiO_2 ratio of about 1.0 to 3.2. This is a grade of sodium silicate used extensively for a number of purposes."

TABLE II

Typical Analyses of Sodium Silicates Used for Coagulation

Brand Name*	Na_2O:SiO_2 Ratio	Degrees Baumé	% Na_2O	% SiO_2	Water	Weight
"N"	1:3.2	41	8.9	28.7	62.4	11.6 lbs. per gallon
"O"	1:3.2	42.2	9.16	29.5	61.34	11.8 lbs. per gallon

*Manufactured by Phila. Quartz Co.

Table II shows the differences between two silicates of the same ratios but concentrated to different degrees. The analyses are average for material produced as uniformly as commercially possible for this type of chemical. The 42.2° Baumé concentration sells for a small premium over the price of the 41° Baumé product. For some purposes a less alkaline grade having a ratio of 1:3.9 may be advantageous despite a still higher cost. The examples cited in the remainder of this article will be with reference to the use of a 1:3.2 ratio, 41° Baumé material.

Preparation of Laboratory Stock Solutions

The following stock solutions are necessary for the evaluation of silica coagulant aids:

1—*Alum:* For jar test dosage and Graf-Schworm coagulant; dissolve 10.0 grams commercial filter alum in one liter of distilled water.

2—*Alum:* For N-sol B only; dissolve 23.9 grams in one liter.

3—*Sodium silicate:* For Graf-Schworm coagulant only; dilute 10.0 grams N brand to one liter.

4—*Sodium silicate:* For N-sol A, N-sol B, and Baylis sol; dilute 174.2 grams N brand to one liter.

5—*Ammonium sulfate:* For N-sol A; dissolve 33.0 grams in one liter.

6—*Sulfuric acid:* For Baylis sol; to 500± ml. of water carefully add 25.50 grams concentrated (96 per cent) acid, then dilute to one liter; 10.0 ml. of silicate solution No. 4 in 100± ml. distilled water should be exactly neutralized to methyl orange end point by 10.0 ml. of this acid. If required, adjust the acid solution by dilution or dropwise addition of concentrated acid.

Stock solutions of other coagulants which are to be investigated should also be prepared dissolving 10.0 grams per liter. Dosage of 1 ml. per liter = 10.0 ppm coagulant.

Preparation of Coagulant Aids

Balis Sol: Dilute 10.0 ml. silicate solution No. 4 with 14.8 ml. water. Add 8.5 ml. acid solution No. 6, mix thoroughly, allow to stand two hours, then dilute to 100 ml. Dosage of 1 ml. per liter = 5.0 ppm. $-SiO_2-$ or 0.29 gpg.

Note: This preparation is an alternative to the Baylis recommendation[2] wherein the adjustment of alkalinity is made in the mixture before aging. Each procedure has points of advantage.

N-sol A: Mix 10.0 ml. silicate solution No. 4 and 5.0 ml. water. Add 10.0 ml. ammonium sulfate solution No. 5, mix well and allow two hours before dilution to 100 ml. Dosage of 1 ml. per liter = 5.0 ppm. $-SiO_2-$.

Graf-Schworm Coagulant: Rapidly mix 3.0 ml. silicate solution No. 3 and 10.0 ml. alum solution No. 1. Use promptly. Maximum value will not be obtained if allowed to age. Dosage of 1 ml. per liter = 7.7 ppm. alum + 0.66 ppm. $-SiO_2-$.

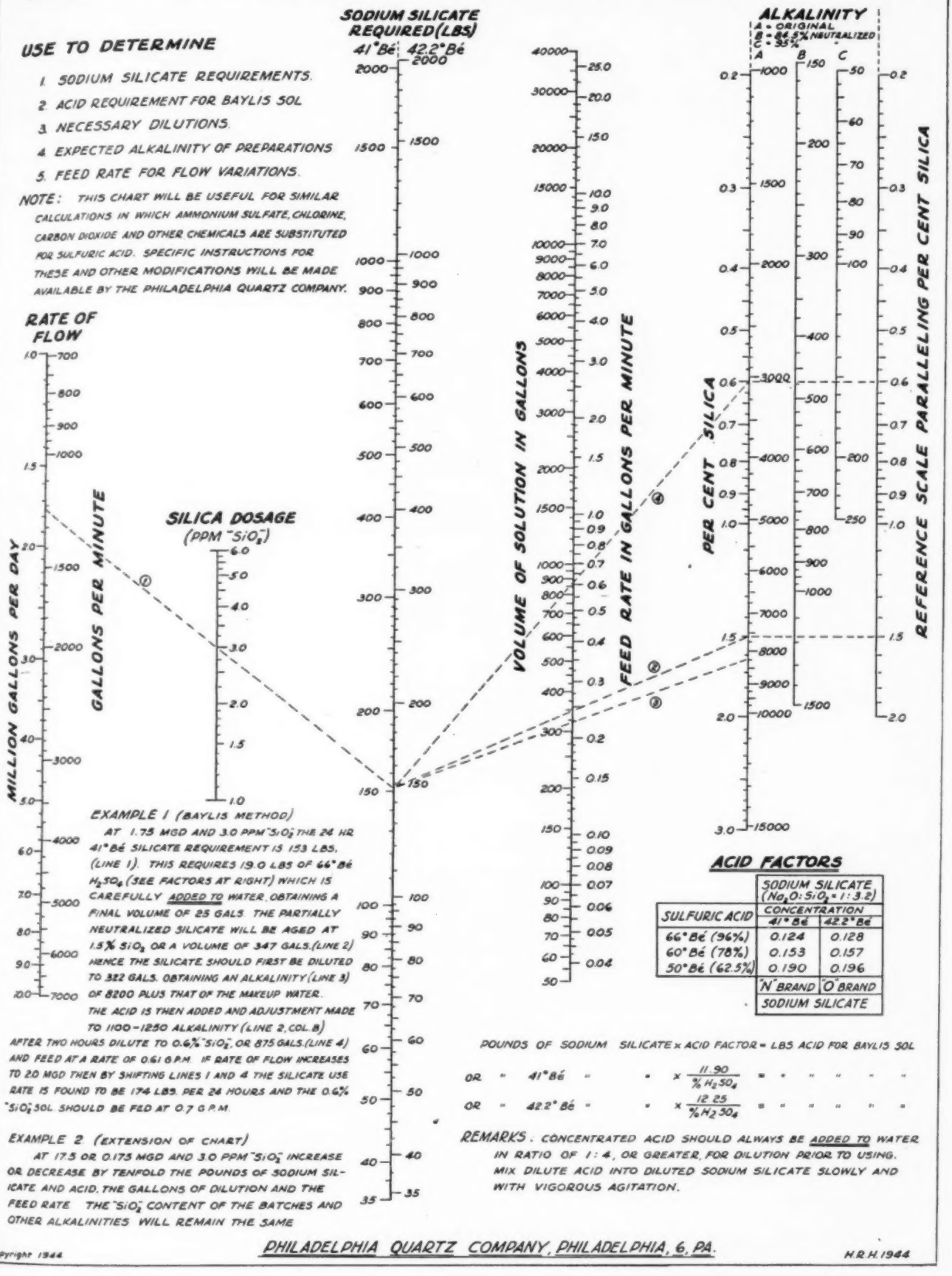
N-sol B: Dilute 10.0 ml. silicate solution No. 4 with 8.7 ml. water. Rapidly mix this with 15.0 ml. alum solution No. 2. Allow 1 hour before dilution to 100 ml. Dosage of 1 ml. per liter = 5.0 ppm. $-SiO_2-$ + 3.6 ppm. alum. In reporting alum consumption, combine the amount in the coagulant aid with that which is added to the water separately.

Unaged Coagulant Aids: In all methods except with Graf-Schworm coagulant an improvement in activity has been observed by aging the silicate preparation. In many instances, however, the better result is not essential and elimination of aging simplifies the process. When an aged silica coagulant aid proves beneficial, a second comparable test should be made with the same mixture which has been diluted to final volume immediately. Aging does not appear to be necessary for use of silica in the lime softening of low magnesium waters nor for certain turbid supplies taken from the Mississippi River provided ample mixing and flocculating capacity is available.

Jar Test Procedure

A preliminary series of jar tests corresponding to current plant practice is required to determine the minimum coagulant dosage yielding water of desired quality. Smaller quantities of coagulant, reducing this minimum as much as one-half, should be included, although in softening operations the lime and soda ash should not be reduced beyond that minimum which is required for softening. Such a series provides standards for comparison of results. A second series containing 1, 3 and 5 ppm. $-SiO_2-$ will narrow the silica range for further study. Except for the Graf-Schworm method, the coagulant should be varied from the minimum allowable when used alone to one-half this amount or less. After determining

CHART FOR PREPARATION OF SILICA COAGULANT AIDS



USE TO DETERMINE

1. SODIUM SILICATE REQUIREMENTS.
2. ACID REQUIREMENT FOR BAYLIS SOL
3. NECESSARY DILUTIONS.
4. EXPECTED ALKALINITY OF PREPARATIONS
5. FEED RATE FOR FLOW VARIATIONS.

NOTE: THIS CHART WILL BE USEFUL FOR SIMILAR CALCULATIONS IN WHICH AMMONIUM SULFATE, CHLORINE, CARBON DIOXIDE AND OTHER CHEMICALS ARE SUBSTITUTED FOR SULFURIC ACID. SPECIFIC INSTRUCTIONS FOR THESE AND OTHER MODIFICATIONS WILL BE MADE AVAILABLE BY THE PHILADELPHIA QUARTZ COMPANY.

EXAMPLE 1 (BAYLIS METHOD)

AT 1.75 MGD AND 3.0 PPM "SiO_2" THE 24 HR 41° Bé SILICATE REQUIREMENT IS 153 LBS. (LINE 1). THIS REQUIRES 19.0 LBS OF 66° Bé H_2SO_4 (SEE FACTORS AT RIGHT) WHICH IS CAREFULLY ADDED TO WATER, OBTAINING A FINAL VOLUME OF 25 GALS. THE PARTIALLY NEUTRALIZED SILICATE WILL BE AGED AT 1.5% SiO_2 OR A VOLUME OF 347 GALS. (LINE 2) HENCE THE SILICATE SHOULD FIRST BE DILUTED TO 322 GALS. OBTAINING AN ALKALINITY (LINE 3) OF 8200 PLUS THAT OF THE MAKEUP WATER. THE ACID IS THEN ADDED AND ADJUSTMENT MADE TO 1100–1250 ALKALINITY (LINE 2, COL. B) AFTER TWO HOURS DILUTE TO 0.6% "SiO_2" OR 875 GALS. (LINE 4) AND FEED AT A RATE OF 0.61 G.P.M. IF RATE OF FLOW INCREASES TO 2.0 MGD THEN BY SHIFTING LINES 1 AND 4 THE SILICATE USE RATE IS FOUND TO BE 174 LBS. PER 24 HOURS AND THE 0.6% "SiO_2" SOL SHOULD BE FED AT 0.7 G.P.M.

EXAMPLE 2 (EXTENSION OF CHART)

AT 17.5 OR 0.175 MGD AND 3.0 PPM "SiO_2" INCREASE OR DECREASE BY TENFOLD THE POUNDS OF SODIUM SILICATE AND ACID, THE GALLONS OF DILUTION AND THE FEED RATE. THE "SiO_2" CONTENT OF THE BATCHES AND OTHER ALKALINITIES WILL REMAIN THE SAME

ACID FACTORS

SULFURIC ACID	SODIUM SILICATE ($Na_2O:SiO_2 = 1:3.2$) CONCENTRATION 41° Bé	42.2° Bé
66° Bé (96%)	0.124	0.128
60° Bé (78%)	0.153	0.157
50° Bé (62.5%)	0.190	0.196
	"N" BRAND	"O" BRAND
	SODIUM SILICATE	

POUNDS OF SODIUM SILICATE x ACID FACTOR = LBS ACID FOR BAYLIS SOL

OR " 41° Bé " " $\times \frac{11.90}{\%\ H_2SO_4}$ = " " " " "

OR " 42.2° Bé " " $\times \frac{12.25}{\%\ H_2SO_4}$ = " " " " "

REMARKS. CONCENTRATED ACID SHOULD ALWAYS BE ADDED TO WATER IN RATIO OF 1:4, OR GREATER, FOR DILUTION PRIOR TO USING. MIX DILUTE ACID INTO DILUTED SODIUM SILICATE SLOWLY AND WITH VIGOROUS AGITATION.

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the best combination and dosage range, additional tests will reveal the most economical treatment. The water temperature of the test samples should conform to that of the supply. Mixing, settling and comparisons should be uniform in all series.

With the addition of silica coagulant aids, excellent results are usually obtained using alum, copperas or lime. In some cases little or no aid is provided for ferric coagulants. Best results are usually obtained when the aid is added *ahead* of the coagulant. In color removal with alum or ferric salts, however, addition of an aged silica sol *after* a floc has partially formed serves to gather the floc and assist in its settling.

Excessive silica dosage should be avoided since poorer results and greater coagulant consumption will be the effect. In lime softening it is frequently possible to use silica followed by lime without any coagulants and in several instances the use of even small amounts of alum or copperas with a silica-lime treatment proved detrimental. It is usually found that the elimination or reduction in coagulants required will more than offset the cost of the coagulant aid and an improved floc is obtained. In up-flow type clarification basins the silicate effectiveness is especially effective because of the floc shrinking and weighting effects.

The jar test experiments will reveal the proper balance of silica to coagulant. In the Graf-Schworm process it is said that the most effective ratios of alum to sodium silicate by weight lies within a range of 7:3 and 8:2. Baylis[4] studied the balance for his sol and stated, "The minimum amount of SiO_2 required to produce nearly maximum aid to coagulation is about 40 per cent of the amount of aluminum sulfate used. There is some additional aid by increasing the amount over the 40 per cent ratio, but the additional aid very likely would not be worth the cost. There is an upper limit, however, which is usually several times the minimum amount, where more silica will prevent good coagulation of the water." Thus the silica dosage is not confined to an extremely narrow range but nevertheless it should be held to a low dosage for economic reasons. With the Baylis sol and N-sol A, three to four parts per million as $-SiO_2-$ has been generally successful in lime softening.

Jar tests also permit a study of possible chemical changes in the silica-treated finished water. The pH may be more favorable due to less coagulant, thereby requiring less correction. In lime softening a substantial improvement in calcium and magnesium removal may be noted. Softer waters are produced when dosages of alum or iron salts have been reduced or eliminated by silica-lime treatment. A more intangible asset of silica treatment is the greater "brilliance" or "sparkle" which may frequently be observed. Geographically the waters which respond to silicate coagulant aids are very widespread. As was earlier indicated, however, the jar tests may, to the contrary, show no improvement from these preparations. The individual characteristics of the water are the determining factors.

Plant Scale Adoption Of Silicate Treatments

When the jar tests have indicated substantially better floc formation with silica aids and the cost factors are likewise favorable, it becomes advisable to conduct a plant test for final appraisal. Some minor adjustments of concentrations may be necessary in view of differences in mixing and settling. Also, many advantages are contributed by silica treatment which cannot be determined in jar tests. The possibility of increasing flow through the clarification units may be determined by watching the turbidity passing to the filters. The effect upon lengthening filter runs with consequent reduction in back-wash can only be determined by choosing a specific treatment and holding it substantially the same over a period of two or three filter runs. One should also consider the effect on the distribution system, but this will take much longer to determine.

The question has often been asked whether any corrosion resistance is contributed by the use of sodium silicate coagulation aids. None is to be expected since the silica is originally added in very small amounts and this is removed in the floc. There is no evidence that silica added for coagulation enters the distribution system. It would, therefore, be necessary to follow filtration with extra sodium silicate, or perhaps with silica sols, to obtain corrosion control from this chemical.

If the silicate method to be used does not involve aging, continuous preparation by means of proportioning devices is relatively simple. It is important not to exceed the maximum suggested concentrations, but since dilution may be great, accurate control is not essential. Proportioning pumps afford a convenient means of feeding the reacting chemicals from concentrated solutions into diluting streams of water which may then join to produce the desired product. The use of concentrated solutions reduces liquid storage problems.

When an aged silica coagulant aid is required, batch preparation must be employed, although means of continuous aging are being studied. From the alignment chart, Fig. 1, it is possible to obtain all essential information for installation and operation of the Baylis method in any size plant. The sodium silicate and acid requirements may be obtained for a 1:3.2 ratio silicate of either 41° or 42.2° Baumé. The volume requirements for batch make-up are based on a 24-hour consumption. If this volume becomes excessive it may be necessary to prepare batches more frequently. Under certain circumstances it is possible to use Baylis sol with safety at 1.5 per cent SiO_2 concentration instead of the indicated dilution to 0.6 per cent. With N-sol A even higher concentrations can be stored. A full consideration of dilution factors in the preparation of Baylis sol will be given in a later article to appear in WATER WORKS AND SEWERAGE.

The chart is also useful for determining the silica feed rate of continuous or batch preparations for coagulation at fluctuating rates of flow. In addition, it can be used, with information later to be released, for neutralization of the sodium silicate with chlorine, carbon dioxide and other chemicals.

In planning for batch preparation of a silicate coagulant aid, it is important to provide a second tank to be filled from the mixing tank and from which the coagulant aid may be applied during the mixing and aging of the main batch. All coagulant aids which are benefited by aging are alkaline in reaction and therefore do not present a great corrosion problem. Earthenware crocks are preferred for the dilution of the sulfuric acid used in the Baylis method. If 96 per cent sulfuric acid (66° Baumé) is used, it should be added to at least four times its weight of water. In N-sol A the ammonium sulfate should not be more concentrated than 10 per cent. The reactant chemicals in these methods should be added slowly to the dilute solution of sodium silicate which is being vigorously agitated by air or mechanical means. Localized gel formation which may be produced by excessively concentrated reactants should be avoided since such gel par-

ticles, even if minute, will not be precipitated with the floc and will carry over onto the filter and reduce the length of filter runs.

Patent Considerations

The silicate coagulant aids described in this article are the only ones known to be in current use or to have been successfully proved in large plant-scale tests. All are patented or covered in pending applications. Whereas, the Graf-Schworm process may involve royalty payment, the other processes described are available without royalty. There has not been an instance known where the patent rights have restricted the use of the process. Municipalities, private companies or individuals planning to use the methods should, nevertheless, obtain permission from the patent holder. Licenses may be obtained by addressing requests as follows:

For Baylis Sol (U. S. 2,217,466): J. R. Baylis, Physical Chemist, Water Purification Division, Department of Public Works, Chicago, Ill.

For Graf-Schworm Coagulant (U. S. 2,234,285); A. V. Graf, Chief Chemical Engineer, Water Division, Department of Public Utilities, St. Louis, Mo.

For N-sol B (U. S. 2,310,009) and N-sol A (patent applied for): The Philadelphia Quartz Co., 121 S. Third Street, Philadelphia 6, Pa.

Summary

Through extensive research several useful silica coagulant aids have been developed and made available for water purification. These are beginning to receive widespread acceptance. They involve the use of sodium silicate, a chemical which serves water treatment in other functions such as corrosion control and the protection of synthetic zeolites which are themselves manufactured from sodium silicates. The chemical can likewise be used to treat concrete to prevent its disintegration by acids, chlorine, alum, ammonium sulfate, carbon dioxide or hydrogen sulfide. It is an inexpensive chemical, the use of which has reduced treatment costs while improving floc formation. Its acceptance to date has been chiefly through its ability to produce good coagulation where other methods have proved inadequate.

REFERENCES

(1) Hay, H. R. Water Purification Methods Involving Sodium Silicates. Jour. A.W.W.A. in press (1944).
(2) Baylis, J. R. Coagulation. Parts 1 and 2. Water Works and Sewerage **83**: 469 (1936); Part 3. Ibid **84**: 221 (1937).
(3) Graf, A. V. and Schworm, W. B. Solution Mixture of Sodium Silicates Improve Coagulation. Water Works Engineering **90**: 1514 (1937).
(4) Baylis, J. R. Silicates as Aids to Coagulation. Journ. A.W.W.A. **29**: 1355 (1937).

Latin American Cities Improving Water Systems

Water supply systems are being improved in fourteen communities in other American republics under the inter-American health and sanitation program. Also, scores of smaller projects or studies for improvement of water supplies are being carried out in Latin America.

The work is one phase of the inter-American health and sanitation program in which eighteen of the other American republics are making a united effort to raise health standards, with the cooperation of the United States.

In El Salvador a nation-wide study of ground water resources has become the pattern for development of sanitary water supplies.

In Mexico projects are being set up for construction of water supply facilities, according to a plan completed by Mexico's National Department of Health for improvement of water supplies in virtually all cities of consequence.

In Paraguay, a detailed study of water supply requirements is being made for the capital, Asuncion, now without a water supply system.

In the Amazon Valley the problem of water supply for virtually all towns and villages is being taken up. Also aid is being given for development of sanitary water supplies at camps of rubber tappers.

Projects started in Mexico are located at Perote and Huajuapan. At Perote, the existing water supply system is being rebuilt to replace one built by the Spaniards more than 200 years ago.

WATER

God's first invention! Older than the light!
He moved upon it, giving His commands,
While all was void, chaotic formless night.
Water came first, then light, then pleasant lands.

"Two gases shall combine." 'Twas thus He wrought,
And it has been His builder since it's birth.
Stone it has built, and in solution brought,
And placed the ores of metals in the earth.

In every earthly thing that grows or lives
It has its part as with the Primal Cause.
It tempers seasons, takes the heat and gives
It back in winter, by the Wise One's laws.

Water for rain and rivers, tears and tide.
For splendid cloud and sparkling dew-drop small,
Vast oceans for the ships of man to ride
And for his power, steam and the waterfall.

From streams and seas to clouds and rain again,
Recycled as the ages come and go.
Now purified and brought to homes of men
For safe refreshing drink and cleansing flow.

—R. R. HOWARD.

(*Ed. Note:* Roscoe Howard, Sup't of Municipal Utilities at Slater, Mo., was referred to in our report of the Missouri Water and Sewage Works Conference meeting as "Poet Laureate" of the Conference. The above poem is a sample of his productions which are the better when the "Poet Laureate" is in form and reads them in person. We have other samples which our readers will see from time to time as space permits.)

Sewerage Order P-141 Undergoing Revision, to Issue Soon

WPB Order P-141 covering the operation, maintenance and repair of sewers, pumping stations and sewage treatment works is at this writing undergoing important revisions which will ease the restrictions on use, inventory and procurement of supplies, materials and equipment for services, pumping stations and sewage treatment works.

Originally intended for release June 1, or thereabouts, advice from Henry M. Evans, chief, sewerage and sanitation branch of WPB indicates that the new order will not be ready for release before mid-June.

We regret that this delay prevents us from publishing the revised P-141 Order in this important issue. Unless additionally delayed it will be printed in the July issue.

ALTERNATE AND SUBSTITUTE PIPE MATERIALS

By A. A. HIRSCH*
State Department of Education
BATON ROUGE, LA.

DURING the continuing but relaxing restrictions on steel, wrought iron, copper-bearing metals and rubber, the water system operator must still utilize other materials, possibly for the duration. This survey has been made to inventory other available pipe stocks and to present their advantages and shortcomings. While the kinds of pipe listed below generally require priority ratings, their adoption in lieu of controlled materials permits availability on desirable and approved projects.

Palliatives

Before planning additional pipe installations for increased capacity, consideration should first be given to the effect of corrective measures in the present system; these restorative operations include (a) pipe cleaning, (b) anti-corrosion treatment of the water, and (c) pipe lining in place.

Pipe cleaning usually restores from 85 to 90 per cent of the original carrying capacity but accelerates subsequent tuberculation unless the water is corrected by anti-corrosion treatment or the pipe interior is covered with a protective lining. A cable drawn scraper is used in pipe sizes down to 2-inch diameter; for 8-inch sizes and larger a pressure driven go-devil may be inserted.

Anti-corrosion water treatments are of several types. The calcium carbonate saturation method is the most widely adopted practice; the desired condition borders on calcium carbonate equilibrium which may be attained, according to the specific case, by (a) aeration for carbon dioxide removal, (b) addition of the alkalies lime or sodium carbonate to increase the pH value, calcium or carbonate concentration, (c) injection of caustic soda when simple pH increase suffices, (d) passage through limestone beds to increase the calcium concentration, alkalinity and pH, and (e) any proper combination of these methods. A calcium carbonate deposit on rough lines or from highly supersaturated solution may be attenuated and distributed over a wider area by impeding crystallization through the use of sodium hexametaphosphate. This material is also widely successful in inhibiting corrosion. A special slowly dissolving form, sold as "Micromet," is adapted to anti-scaling and anti-corrosion protection of domestic hot water lines. Other effective inhibitors are sodium silicate and proprietary organic products, mainly plant extracts. Corrosion of bacterial or plankton origin may be controlled by supplying dissolved oxygen or by some variety of chlorination, usually chloramination or break-point dosage.

Pipe lining in place is limited at present to cement mortars; these reduce the bore slightly but smooth the walls. The overall effect is a gain in stability and hence in long term delivery. In the Tate process a centering mandrel is pulled through the cement mortar thereby squeezing a thin coating on the walls; this method is adapted for use in small and medium sized mains. In 30-inch and larger lines the "Centriline" method is employed, in which a centrifugal machine slings the mortar forcibly against the pipe walls where it is mechanically troweled to a smooth dense lining.

Extensions

When additional piping is required for extensions of service, this need obviously can be satisfied only by new construction, and in such instances recourse to alternate and substitute materials is in order. As amended January 22, 1944, the U-1 order permits: (a) new construction not exceeding $1,500, (b) domestic extensions which do not require more than 400 pounds steel, 1,800 pounds cast-iron, or 1,000 pounds of lead products, or combinations of these materials as stipulated, (c) use of any materials for mains 4 inches and smaller, (d) use of cast-iron and the non-metallics for mains larger than 4 inches but with steel allowed where special conditions warrant, and (e) an unrestricted procurement for inventories totaling less than $10,000 instead of the previous 60 per cent limit. Non-metallic pipe is restricted to a length not exceeding that if cast-iron were being used. Certain essential extensions for the military or industry may be built valued to $5,000.

Copper tubing, frozen in inventory, has been released by Supplementary Order U-9-c-4, amended January 24, 1944, but only for underground service outside buildings. The WPB Utilities Order U-1, issued February 24, 1943, assigns an AA-1 rating to water systems for maintenance, repair, operating supplies and replacement materials following a breakdown.

Alternate and substitute pipe line materials may be grouped for purpose of discussion into the following classes: (1) cement products, (2) metals, (3) plastics, (4) limited use materials, and (5) impractical specialties.

Cast-iron pipe, on which restrictions are the mildest, is so familiar that discussion is superogatory. Screw joint service pipe of cast-iron is produced in sizes from 1¼ to 2 inches, and is procurable with cement linings.

I. CEMENT PRODUCTS

1.1 Concrete Pressure Pipe

Tentative emergency specifications for reinforced concrete pressure pipe have recently been prepared by the American Water Works Association.[1] Three types of pipe are covered as listed below to show the range of sizes and working heads:

Class	Designation	Sizes, in.	Max. operating Head,-feet
A	Steel cylinder reinforced	20-150	600
B	Poured non-cylinder reinforced	20-150	100
C	Centrifugal reinforced	6-84	150

This material is being increasingly selected for raw water transmission lines, especially through swampy terrain. A 33-mile length of 39-inch bore Class A pipe has recently been described.[2] Long feeder mains, having a minimum of fittings, is their principal application to distribution systems, particularly if the water is corrosive. In Chicago two miles of 36-inch pipe, Class C, were laid to supply a new war plant.[3] This installation was with Lewistown Prestressed pipe in which the inner layer was spun in a centrifugal form strung through longitudinally with strained rods and then steam cured before wrapping with stretched steel wire to produce a compression in the pipe wall. A 1-inch concrete layer poured around the wire protected it against soil corrosion. No difficulty is experienced with concrete pipe in satisfying the leakage limitation of 250 gallons per inch diameter per mile per day. Shallow well casings, perforated screens, culverts and sewers are other uses.

Joints are of three types: collar, lock joint with reinforcing tied together and plastered, and bell and spigot.

Sources

American Pipe & Construction Co., P. O. Box 3428, Terminal Annex, Los Angeles, Calif.
Concrete Conduit Co., 899 La Cadena Ave., Colton, Calif.
Gifford-Hill Pipe Co., 412 Texas Bank Bldg., Dallas, Tex.
Hume Pipe of New England, Inc., Swampscott, Mass.
Lewistown Pipe Co., Hillside, Ill.
Lock Joint Pipe Co., Ampere, N. J.
Price Brothers Co., P. O. Box 825, Dayton, Ohio.
Spokane Concrete Pipe Co., P. O. Box 1033, Spokane, Wash.
United Concrete Pipe Corp., 1347 W. 208th St., Los Angeles, Cal.
Utah Concrete Pipe Co., 1212 S. State St., Salt Lake City, Utah.

Concrete Well Screen

Kelly Well Co., Inc., Grand Island, Nebr.

1.2 Asbestos-Cement Pipe (A/C Pipe)

Asbestos-cement pipe is made from a mortar containing equal volumes of asbestos fiber and Portland cement; this mixture on a weight basis is 15 per cent asbestos and 85 per cent cement. Already familiar in the water works field, this material ranks competitively against iron and steel lines and hence is more than merely a substitute. Experimental manufacture started in 1913. Its first application was as a sea water conduit in Italy to furnish fire protection and a water supply for flushing streets. Some 40,500 miles of A/C pipe had been installed throughout the world prior to the outbreak of World War II.

Federal specifications SS-P-351 cover quality of cement-asbestos piping for government use. The National Board of Fire Underwriters has examined and reported favorably on these products, from outstanding American manufacturers, for use in distribution systems.

Advantages of A/C pipe are its light weight, resistance to corrosion by sodium chloride, hydrogen sulfide, carbon dioxide and dissolved oxygen in water, inertness to soil reaction and

*Director, School on Water Supply and Sewerage.

electrolysis, permanent wall thickness not reducible by corrosion, salvage value for relaying, ease of cutting with a handsaw, it may be tapped the same as cast-iron (a separate tap is advised to be used on this material only), installed cost is claimed to be 20 to 30 per cent lower than with ferrous piping although the price f.o.b. is competitive, and its Williams-Hazen flow coefficient may be conservatively taken as 140.

The characteristic disadvantage of A/C pipe is its low structural strength, approximately one-quarter that of an iron line. This is reflected in the strength of threads for corporation cocks and in its susceptibility to direct loading. A minimum cover of 2 feet is recommended.

Domestically manufactured products described below are: Transite, Century, Eternit and Roxite. Foreign products are trade named: Duralita, Everite, Durabest and Italite.

1.2.1 Transite A/C Pipe

Transite pipe is formed under pressure, as a homogenous mass, over a full length rotating steel mandrel and is then steam cured to accelerate hardening. Before shipment each length is tested at four times the expected working pressure.

Seventeen sizes are available from 3 to 36 inches diameter. A 2-inch size is used as a taper fitted electrical conduit. Pressure classes are 50, 100, 150 and 200 p.s.i. Standard length is 13 feet. Above the 8-inch size an adapter is needed when jointing into a cast-iron bell.

The joint, a Simplex sleeve, is jacked into position over two rubber sealing rings. As this joint lacks pull-out strength, buttressing is required at sharp bends. The flexibility of the rubber rings permits a 12° deflection without leakage; this property has been found valuable in accommodating soil subsidence and earth movement near bomb craters. Gum rubber rings are reported to retain a high degree of elasticity after many years in service, the oldest record being 66 years.[4] An interesting advantage gained by resilient seals is the reduction of water hammer pressures to about 72 per cent of that developed in a similar cast-iron line.[5]

Source

Johns-Manville Co., 22 E. 40th St., New York, N. Y.

1.2.2 Century A/C Pipe

This pipe is formed in six overlapping plies spirally wound over a mandrel under pressure. Available sizes range from 2 to 12 inches, in lengths of 10 and 13 feet. Standard pressure classes are 100 and 150 p.s.i., but 200 p.s.i. piping may be produced as a special. The joint, a malleable iron Dresser compression coupling, which permits 4 to 6 degrees deflection in the line, has the advantage of being connected simply with a wrench.

Source

Keasbey & Mattison Co., Ambler, Pa.

1.2.3 Eternit A/C Pipe

This pipe, introduced just recently, is formed by the extrusion process, which method is claimed to allow superior control on density and accuracy. Diameters up to 6 inches are available in 13-foot standard lengths.

Source

The Ruberoid Co., 500 Fifth Ave., New York, N. Y.

1.2.4 Roxite A/C Pipe

Roxite is manufactured by high pressure extrusion and deairing to produce a dense, strong wall. For severely corrosive duty a resin coating or impregnation provides protection. Sizes range from ¾ to 8 inches ordinarily, but larger pipe up to 12 inches are furnished on special order; lengths are supplied up to 14 feet. Thicknesses are designed to withstand 150 p.s.i. working pressure. Couplings are patented "Flexlock" rubber sleeves.

Source

The United States Stoneware Co., Akron, Ohio.

2. METAL

New metal products to replace the familiar galvanized iron, copper, brass and lead piping and tubing are available only in small diameters. As previously noted, copper may be used only from stocks on hand or procurable from other water utilities. No priorities are involved in obtaining lead or lead alloy service pipe. Wiping solder and brass nipples are permitted by government orders to complete the installation.

2.1 Asarco "Tube-Loy"

This metallic pipe is extruded from essentially pure lead alloyed with 0.015 percent magnesium, 0.02 per cent calcium and 0.23 per cent tin to increase its hardness, shock resistance, strength, stiffness, ductility and improve its jointing properties but reduce its creep rate. This alloy hardens with age and is corrosion resistant except with the more aggressive waters, in which a too high lead pickup may ensue. Its weight is lighter and cost is less than for AA lead pipe. A salvage value may be realized by remelting old tube-loy pipe to obtain scrap lead.

Type A resembles the conventional AA lead services, with added strength. Sizes range from ¾ to 2 inch. Joints are wiped or sweated.

Type K, suited for pressures up to 125 p.s.i. is thinner and uncoils easily. Sizes are ⅜, ½, ⅝, ¾ and 1 inch, coiled in 30, 45, 60 and 100 foot lengths. Joints may be wiped or sweated as above. Grinnell galvanized malleable iron "Superseal" flared fittings with a long 10° taper permit strong connections for domestic piping. A 45° flare in superseal connectors is also used.

Source

American Smelting & Refining Co., 120 Broadway, New York.

2.2 Bundyflex Copper Coated Steel

The copper coating both inside and outside of this steel tubing is fused on at high temperature into the pores of the base metal, and is claimed to form a copper-steel alloy. This product is soft, ductile, flexible, can be flared, soldered, brazed or welded. It can be used with any of the fittings ordinarily used with copper tubing, either sweat or compression type. This tubing is twice as strong as copper and has much higher resistance to vibration fatigue. Ultimate bursting strength varies from 5,000 to 25,000 p.s.i., depending on the wall thickness and diameter of the tubing. It is widely used by manufacturers of automobile hot water heaters. Sizes range from ⅛ to ⅜ inch o.d. in 25-foot coils, and from 7/16 to ⅝ inch in 12-foot lengths.

Source

Everhot Products Co., 2055 W. Carroll Ave., Chicago, Ill.

3. PLASTIC PIPE AND TUBING

Plastics, in general, are synthetic resins of high molecular weight polymerized from simple compounds by means of heat, pressure and catalysis. Based on composition, plastics have been grouped by the Plastics Catalog[6] into sixteen basic varieties, each with characteristic properties which adapt them to special applications. About 250 trade names of plastic compositions are now produced. For fabrication into pipe and tubing, materials are desirable which can be formed by dry extrusion, as this is the most efficient method of manufacture and produces tubing of unlimited length. Only a few specialties in the way of tubing are now produced by lamination. The strategic demand for certain of these resins places further limitations on the availability of pipe stock.

Present plastic compositions invading the pipe and tubing market belong to the polyvinylidine chloride and cellulose acetate butyrate types. These elastomers are replacing metal and rubber conduits for defense structures, battleships, army camps, stirrup pumps and similar applications. Also a variety of specialty tubes is being produced from other types of resins for specific applications, mainly in connection with the war effort. According to the concensus of present opinion no serious displacement of the metals from water pipeline service is foreseen. However these prophesiers fail to appreciate obvious advantages peculiar to some plastics. A plastic pipe will usually eliminate need for protection against freezing; neither will it corrode. In domestic hot water lines the temperature drop between heater and fixture will be minimized; acid may be used with impunity for scale removal. Light weight and visibility, with some types, are other desirable features. In Germany, Mipolam, and in the U.S.S.R., Textolite, are plastics substituting for metals in water supply systems.[10] Only the three materials described below are of immediate interest, but when peace returns, other plastic compositions will undoubtedly become available for water supply specialties.

3.1 Saran

Saran, a flexible, yellowish, translucent polyvinylidine chloride product, which is replacing copper tubing in approved housing projects at a comparable cost, so far has been the principal and most promising plastic offered for water services. Its tensile strength ranges from 4,000 to 8,000 p.s.i. Hot water temperatures to 170° F. are withstood continuously; up to 212° F., intermittently. Saran does not support combustion; it is rated as self-extinguishing, however, since it melts near 310° F., fire or high temperature is destructive. Sunlight darkens its color, so pipe intended for exposure is black.

In a study of its properties for the National Association of Master Plumbers, Dawson and Kalinske[8] reported that Saran piping is hydraulically smooth, and water hammer pressures, by virtue of its elasticity, were only ½ to ⅓ as great as in iron

pipe. As its heat conductivity is only 1/4,500 that of copper, frost protection in services and inappreciable temperature loss in hot water lines is afforded. Deposits do not tend to adhere. White rats were observed to attack this material if starved or thirsty. Saran pipe expands 0.83 feet per 100-foot length per 100° F. temperature change, therefore distortion must be controlled. Low temperatures cause an embrittling effect.

At a magnesium plant, the electrical insulating properties of Saran enabled replacement of less durable rubber pipe for water jackets in rectifiers without grounding across 600 volts.[9]

Black Saran pipe is available in ½, ¾, 1, 1¼, 1½, 2, 2½, 3, 3¼ and 4-inch sizes. Its weight is one-quarter that of corresponding iron pipe. Bursting pressure varies with size from 620 to 1,500 p.s.i. at room temperature. A representative line of molded Saran screwed fittings is made. Joints may also be made by autogeneous welding after first melting the abutting ends on a hot plate at 400° F., or by a portable girth type electric heater.

Flexible tubing, of high fatigue strength, is furnished in various wall thicknesses from ⅛ to ¾ inch outside diameter. Bursting pressure, dependent on size, varies from 580 to 1,200 p.s.i. at ordinary temperatures. Couplings are the flared compression type, molded from Saran resin.

Source

The Dow Chemical Co., Midland, Mich.

Licensees

Extruded Plastics, Inc., New Canaan Ave., Norwalk, Conn.
Haveg Corp., Newark, Del.
Hodgman Rubber Co., Framington, Mass.
Godall Rubber Co., Inc., 5 S. 36th St., Philadelphia, Pa.
Elmer E. Mills Corp., 153 W. Huron St., Chicago, Ill.
Western Felt Works, Acadia Synthetic Products Division, 4035 Ogden Ave., Chicago, Ill.

Distributors

American Radiator & Standard Sanitary Corp.
Crane Co.
Metal Goods Corp.

3.2 Tenite

Tenite II is a cellulose acetate butyrate plastic made according to the manufacturer's formula 201 in transparent varieties and formula 205, containing an ultraviolet inhibitor, in the opaque, gray type. At low cutting speed it machines like metal. By immersing in hot water it may be shaped to curves. A test piece holding 80 p.s.i. water pressure for over two years held its dimension within 2 per cent. Rodents and insects are not attracted, according to claim. It is a definite fire hazard, being rated similar to bulk newsprint. Hot water temperature is limited to 140° F.

Sizes range from 3/16 to 2½ inches in 29 items. Heavy wall tubing is cut in 8 to 12-foot lengths; 20-foot lengths are specials. Joints are made either with flared end compression fittings or by heat expanding one end to receive the mate in telescope fashion, then sealing with a suitable solvent or Duco cement.

Source

Tennessee Eastman Corp., Kingsport, Tenn.

Licensee

Extruded Plastics, Inc., New Canaan Ave., Norwalk, Conn. (Lists as Tulox TT seamless tubing.)

3.3 Plastitube and Plastiflex

These are rigid and flexible tubing, respectively, extruded from cellulose acetate butyrate in standard 12-foot lengths and 60-foot coils. Sizes range from ⅛ to 2 inches outside diameter.

Source

R. D. Werner Co., Inc., 380 Second Ave., New York, N. Y.

4. LIMITED USE OF PIPE

4.1 Orangeburg Fiber

This light weight pipe is composed of 25 per cent cellulose fibers and 75 per cent coal tar pitch. The fibers are first felted and dried, then impregnated under vacuum to assure complete penetration. Advantages of fiber pipe are its economy, toughness, ease of cutting, light weight (16 per cent that of steel), protection against freezing, high flow factor and absence of corrosion. In shrinking soils it deflects with settlement but does not crack. Its principal disadvantage is that use must be confined to low head or non-pressure applications, such as for vents, downspouts, drains, chemical feed conduits and tile sewage disposal fields. When used for sewers its tight tar joints are claimed to prevent entrance of roots. Its inertness permits use in oil fields brine disposal systems. When laid underground it must be well covered and tamped; if suspended, rigid supports are needed to prevent sagging. Even were this pipe suitable to carry drinking water the coal tar impregnate would likely cause chlorphenol tastes with free chlorine. Its short length is something of a drawback.

Sizes are 3, 4 and 5-inch diameters in 8-foot lengths and 6 and 8-inch diameters in 5-foot lengths. Fiber fittings include bends, ells and adapters for connecting either to threaded or to bell and spigot pipe.

Joints are made by driving a 2° tapered sleeve over a corresponding taper on the pipe ends. A field tooling lathe is supplied to dress a taper on job cut lengths. Cementing compound is unnecessary as the friction is claimed to develop sufficient heat during driving home to soften the pitch and thereby seal the joint. A pull of 1,500 pounds is required to separate the joint in a 4-inch pipe.

Source

The Fibre Conduit Co., Orangeburg, N. J.

Distributor

Crane Co.

4.2 Wood Pipe

Pine, fir, redwood, red cedar and cypress are the species selected for making wood pipe. The bored type is available up to 4-inch diameter in 12-foot lengths. Large quantities are being shipped overseas for army use. The banded type is assembled from tongue and groove staves, machine strapped at the factory with galvanized bands, covered with pitch and rolled in wood shavings. Large sizes are assembled in the field as a continuous cylinder, bound together with rods and lugs. Such pipe is widely used for penstocks under heads as high as 150 feet. This pipe is suitable for raw water transmission from a distant source to the treatment plant. The preferred method for installation is either deep burial or support on racks with allowance for ventilation underneath. Surface installation allows premature decay at the ground line. Termites do not invade the wood if saturated with water. Lines for intermittent use are pressure creosoted.

Advantages of wood pipe are cheapness, light weight, fairly long life—from 20 to 50 years, depending on circumstances—high stable carrying capacity, frost resistance, absence of expansion joints and freedom from soil corrosion and electrolysis effects, except at the metallic binders. Its disadvantages are danger of collapse from weight of backfill, particularly if empty or under vacuum, ground line decay where resting on the soil and possible failure from corrosion of the retaining bands. High leakage losses are experienced, especially under varying pressures. Since water distribution systems are subject to continual water hammer, wood pipe is definitely unsuited for this application. Leaching of color and resins decreases with age.

Machine banded pipe for working heads up to 250 feet is available in sizes from 6 to 48 inches and in lengths from 12 to 20 feet. A lap joint or collar, wood or metal, is used for connections. Continuous stave pipe is obtainable in diameters from 12 to 192 inches. Joints in the staves are staggered within a short segment so that additional tension rods placed there can provide rigidity. A tapered steel tongue is driven into the butt ends of the staves to secure positive connection.

Sources

W. E. Caldwell Co., 2236 Brook St., Louisville, Ky.
Federal Pipe & Tank Co., 6851 E. Marginal Way, Seattle, Wash.
Michigan Pipe Co., 504 Phoenix Building, Bay City, Mich.
National Tank & Pipe Co., 2301 N. Columbia Rd., Portland, Ore.
Redwood Manufacturers Co., Hobart Bldg., San Francisco, Cal.
A. Wyckoff & Sons Co., 1 Home St., Elmira, N. Y.

5. JUTE SUBSTITUTE

Fibrex, a sanitary paper packing with twisted pulp core and braided jacket, treated to retain sterility, may be packed into a joint the same as jute.

Source

Hydraulic Development Co., 50 Church St., New York, N. Y.

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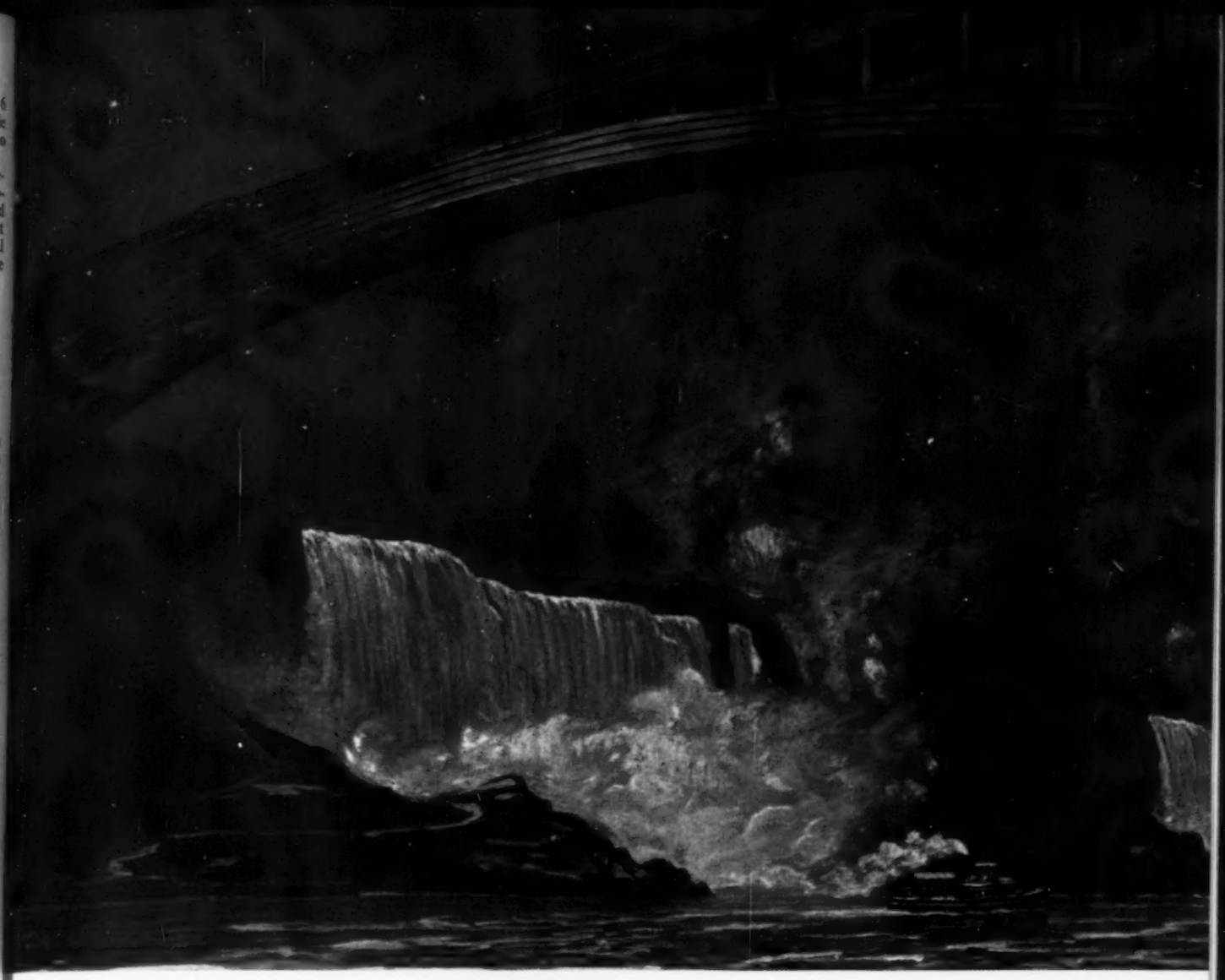

RAINBOW OF STEEL . . .

Symbol of the ties that bind Canada and the U. S. together in friendship is the new Rainbow Bridge recently erected across the gorge below Niagara Falls. Built in harmony with the rugged Niagara landscape, it is a promise of still greater cooperation between the two countries as well as a permanent answer to the challenge of the deep gorge and the swift currents that flow through it.

This bridge also epitomizes the growth of the Niagara region as one of America's most important industrial centers. With the Falls as a source of almost unlimited hydroelectric power, this area has become a fountainhead of strength for the nation at war. Out of its factories are pouring huge supplies of chemicals, chemurgical products and many other essential materials. And Niagara Alkali, pioneer chemical manufacturer in this district, is helping to set a new pace in speed of production and efficiency of service in meeting these vital needs.

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OXIDANTS AND REDUCTANTS IN SEWAGE PLANT EFFLUENTS AND STREAMS

By ROLF ELIASSEN
Major, Corps of Engineers,
Second Service Command
NEW YORK, N. Y.

THE relationship between stream conditions and the quality of effluents from sewage treatment plants employing biological secondary processes of treatment has been the subject of considerable discussion of late among sanitary engineers. Differences of opinion have arisen over the relative merits of the relative stability and B.O.D. tests as indices of effluent quality. Both tests have been in use for many years; the test selected frequently depending upon the laboratory facilities available and the analytical skill of the operating personnel. The two tests are quite different in nature and bear no direct relationship.

A revaluation of the significance and applicability of each test and a study of fact as involved in the two tests, together with evaluation of the influence of nitrates on the receiving stream is timely. It should serve to clarify the situation and suggest practical criteria in determining effluent quality and its relation to the stream.

Proper Basis for Judging Effluent Quality

The proper basis for judging the quality of effluents from sewage treatment plants should be the degree to which the particular effluent meets the requirements of the criterion established for the receiving stream conditions. As far as oxygen in the stream is concerned, two criteria present themselves. One is governed by the necessity for preservation of fish life. This usually calls for the maintenance of at least 3 p.p.m. of dissolved oxygen in the stream at all times. The other criterion is the control of odor nuisances and prevention of septic conditions in the stream. The design of any sewage treatment plant should be predicated upon the ability of the receiving stream to absorb the plant effluent in such a manner that it meets one of the above criteria (or perhaps bacteriological criteria) whichever has been established by stream control authorities.

Characteristics of Effluents

Primary treatment plants are characterized by effluents which contain appreciable amounts of organic

The Author

matter in the form of dissolved, colloidal and suspended solids. Tests indicate that the effluents are high in B.O.D., ammonia and organic nitrogen and usually devoid of dissolved oxygen, nitrites or nitrates. Considerable dilution is necessary to maintain acceptable conditions in the receiving stream.

Secondary treatment plants operating at normal efficiency are characterized by effluents which are low in organic matter, as measured by the B.O.D. test. Low rate trickling filter plants yield effluents which frequently are high in nitrates and relative stability. On the other hand, operating data on high rate filter plants indicate that the effluents contain little or no nitrites or nitrates and have a low relative stability even though the B.O.D. values may be the same as those of the low rate filters. In other words, the nitrification of organic matter proceeds further in low rate than in high rate filters. Activated sludge plants can impart either a low or a high degree of nitrification to the organic matter depending on the amount of air used, length of aeration and other factors which control the operation of this type of plant.

The Relative Stability Test

Consideration should first be given to the reactions taking place in the relative stability test bottle. Assume that a 150 ml. bottle has been filled with the effluent from a low rate trickling filter, with the requisite amount of methylene blue indicator added. In addition to other substances, this effluent will contain organic matter chemically classified as reductants and dissolved oxygen, nitrites, nitrates, and sulphates, termed oxidants. The test procedure calls for incubation of the bottle at 20 deg. C. until the methylene blue turns colorless. The period of incubation in days is noted and converted to a percentage known as the "relative stability." This percentage is based on the arbitrary assumption that a sample in which methylene blue retains its color for 20 days is 99 per cent stable. Intermediate values follow a logarithmic relationship between oxygen demand and time.

During the course of the incubation the organic matter serves as food for the organisms present in the sewage sample. These organisms utilize oxygen in their life processes. Oxygen is most readily obtained when in the free state as dissolved oxygen. When this is no longer available, oxygen is obtained from other oxidants such as nitrites, nitrates and sulphates. The biochemical reactions taking place result in the oxidation of organic matter and the reduction of oxygen and other oxidants. When these oxidants are virtually used up the methylene blue loses its color and the test is completed.

The loss of color of methylene blue is brought about by a chemical oxidation-reduction reaction. Methylene blue is an organic dye compound which can be oxidized or reduced by means of bacteria the same as other organic matter. It has the property that when in the reduced state it is colorless, known as leuco-methylene blue. If oxygen were added to a solution containing the reduced compound it would be oxidized to the blue color. This change of color occurs at an oxidation-reduction potential of approximately zero. Thus, methylene blue serves as an indicator of zero oxidation-reduction potential. This is the use to which it is placed in the relative stability test.

Oxidation-Reduction Potentials

It is not the purpose of this short paper to describe all of the physical and chemical factors involved in oxi-

Note: Since the contribution of this article Major Eliassen has been made Chief of Sanitation Section, 9th Service Command Area, with headquarters at Ft. Douglas, Salt Lake City.

dation and reduction reactions. However, a brief consideration of oxidation-reduction potentials might serve to give a clearer picture of what lies behind the relative stability test and other phases of sewage analysis.

Oxidation-reduction potential is not an abstract term borrowed from the realm of physical chemistry. It is a definite potential which may be measured directly in volts by means of a Wheatstone bridge, just as may a battery or any other electrical cell. The range of voltages met with in sewage treatment plants usually lies between +0.4 and —0.4 volts when referred to the standard hydrogen electrode.

The electrical measurement of this potential is based on a cell, or rather two half-cells, one half of which is the sewage, and the other half a standard hydrogen electrode. The latter is the reference electrode whose potential is arbitrarily assumed as 0.0 volts. For practical purposes a standard calomel electrode is used and a correction factor of +0.28 volts applied because the potential of the calomel electrode is 0.28 volts higher than the standard hydrogen electrode.

In the everyday use of a pH meter the same procedure is adopted. A calomel electrode forms half the cell and a glass electrode is placed in the sewage to form the other half cell. In reality, the measurement of pH is a measurement of the oxidation-reduction potential existing from the difference in concentration of hydrogen ions in the sewage and in the standard hydrogen electrode.

It is not necessary to understand the mathematical relationship upon which this potential is based in order to apply it to practical uses. It is sufficient to state that the oxidation-reduction potential expresses a mathematical relationship between oxidants and reductants in the sewage. The higher the percentage of oxidants the more positive the potential; the higher the percentage of reductants, the more negative the potential. This relationship has a direct practical significance in that positive potentials represent an aerobic or oxidizing environment while negative potentials represent an anaerobic or reducing environment.

The oxidation-reduction potential is a measure of the intensity of oxidation and not a quantitative measure of oxidizing or reducing capacity. The latter are measured by the concentration of oxidants and reductants. A direct parallel exists with the pH determination. The pH indicates the intensity of acidity or alkalinity but not the total of either available in the liquid. The quantitative measurements of acidity and alkalinity are necessary in order to determine the amounts of each present. Only as hydrogen or hydroxyl ions become dissociated do they influence the pH. Similarly, only as oxidants or reductants are dissolved and enter the molecular or ionic state do they exert their influence on the oxidation-reduction potential.

Oxidation and reduction must always be associated together. One of the fundamental laws of nature must be followed in all chemicals reactions, namely, for every action there must be an equal and opposite reaction. Thus, for every oxidation, there must be an equal and opposite reduction until a final state of equilibrium is attained between oxidants and reductants. In any oxidation-reduction reaction, the oxidants are reduced and the reductants oxidized to approach equilibrium. These are the fundamental reactions taking place in the relative stability test bottle, with the organic matter acting as reductants and the dissolved oxygen, nitrates, nitrites, sulphates, serving as oxidants.

When the aforementioned oxidants are exhausted aerobic conditions cease to exist in the sewage. The biological environment in the sewage then becomes anaerobic or septic in character, with consequent formation of odorous compounds. Thus, the relative stability test indicates the length of time aerobic conditions, or a positive oxidation-reduction potential will be maintained in the sewage during the course of biochemical oxidation of the organic reductants utilizing the oxidants such as dissolved oxygen, nitrates, nitrites, and sulphates present in the effluent at the time of a sampling.

By itself, the relative stability test has little practical significance. Taken literally, the test would indicate the length of time aerobic conditions would be maintained if no oxidants were added by the receiving stream and no absorption of oxygen took place from the atmosphere. These conditions do not ordinarily prevail in any natural stream. An exception is an ice-blanketed stream without side entry feeders.

As far as the operator is concerned, the relative stability test is useful in the routine operation of a secondary treatment plant as an index of performance. If the relative stability is high, indications are that sufficient oxidants are present in the effluent to take care of the oxidation of the organic matter without creating a nuisance in the stream. A low relative stability might possibly indicate either too much organic matter or too low a quantity of oxidants in the effluent if not enough dilution were provided by the stream. Final opinion on the quality of the effluent can only be based on its effect on the stream.

Effect of Nitrates in a Stream

Some engineers may still prefer the relative stability test to the B.O.D. test even though the former gives no quantitative measurements, because it does take into account the effect of nitrates in effluents. This brings up the question of the significance of nitrates in sewage plant effluents and in the receiving streams.

Consideration of oxidation-reduction potentials will reveal that if any dissolved oxygen is present in the stream, the potential will be positive to such an extent that most of the nitrates and other oxidants will not be utilized to furnish oxygen for the bacteria. Nitrates would only be utilized when the receiving stream affords such a limited dilution that essentially all of the dissolved oxygen is exhausted. In other words, the nitrates act as a last line of defense in preventing onsets of anaerobic conditions in the stream. When most of the nitrites, nitrates, sulphates, and similar oxidants are reduced, the oxidation-reduction potential is approximately zero and septic reduction of organic matter will begin, with the production of odors and other nuisances.

It is not sound engineering practice to depend on an effluent with a B.O.D. of such a value that conditions in the river are so close to becoming septic that the nitrates must furnish oxygen. Sewage treatment plants should be designed and operated in such a manner that a safety factor of some dissolved oxygen should always be present in the stream.

Where the preservation of fish life is the governing factor in streams, the dissolved oxygen should not be permitted to fall below 3 p.p.m. Then the presence of nitrates will have no effect inasmuch as the oxidation-reduction potential will be so high that the nitrates will not be reduced and thus will not furnish the oxygen for oxidation of the organic matter. The only possible effect on fish life might be an indirect one in that nitrates "fertilize" the water and aid algae growths. However, the disadvantage of algae growths stimulated by nitrates are so many that

every attempt should be made to eliminate them wherever possible.

Proper Concepts of Stream Oxidation

As far as oxidation of organic matter in the stream is concerned, it makes no difference whether a plant effluent is low or high in nitrates, except when the stream is on the ragged edge of turning septic. It follows that it makes no difference whether the effluent is from a low or a high rate tricking filter plant or from an activated sludge plant providing a low or a high degree of nitrification. Regardless of the type of plant, all effluents should represent such a degree of treatment that the quantity of reductants or organic matter discharged into the stream will be low enough to permit an oxidizing environment to exist at all times according to the criterion established for stream condition.

The principal factors which govern whether this criterion will be met are the relative flows of effluent and stream, the reductants in the effluent, the oxidants in the stream or entering the stream through reaeration, and the relation between these reductants and oxidants. The concentration of reductants is indicated by the B.O.D. test which serves as the index of effluent quality. The concentration of oxidants in the stream is indicated by the dissolved oxygen test and serves as an index of the oxidizing capacity of the stream. The relation between reductants and oxidants as they exist in the stream is an index of the state of oxidation and is measured by the oxidation-reduction potential.

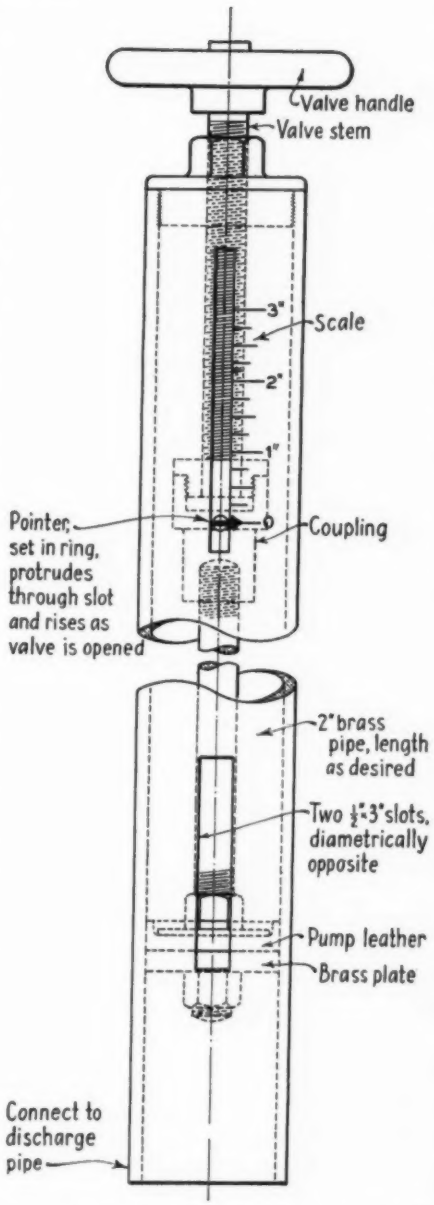
SPECIAL VALVE FOR SOLUTION FEED CONTROL*

WHEN we started the water plant at Danville, Ill., lime and iron sulfate were used for coagulation. The iron sulfate came in large crystals, the lime in lumps. Each chemical was slaked in separate tanks. The solutions were pumped to constant head (30-inch) tanks located in the top of the filter room, with overflow return to the basement storage tanks. Feed pipes were connected to the low service mains in the basement, and graduated 2-inch globe valves were used to control the solution feed. This method of control was not a success.

We then made a disc 12 inches in diameter, with a shaft extending above the head tanks, with star handles set vertically over the portholes. These holes started at ¼-inch and advanced ¼-inch until a 2-inch size was reached. These were only partially successful. The writer then designed the valve shown in the accompanying sketch.

This solution feed control valve was very simple in both construction and operation. It was made from a piece of 2-inch brass pipe, near the bottom of which were 2 ports, ½" x 3". A discarded 2-inch valve produced the cap and an extension stem with which to operate. The lower disc was made from common pump leather. At the top of the pipe another slot was cut for the pointer to indicate the height of lower disc above the bottom of the port. For example, if the lower disc was raised ½-inch, it would produce an opening of 1 sq. inch. Its construction was simple and inexpensive.

This valve gave entire satisfaction and was later used on alum solutions until dry feeders were installed. We were able to pass this design on to several other filter plant operators as this type of valve could be used on any solution feed system.



Danville Solution Feed Control Valve

*A contribution from Martin M. Symons, Chief Engineer, Interstate Water Co., Danville, Ill.

Chemistry Made Easy

Under the title "Chemistry Made Easy," Dr. Cornelia T. Snell, Consulting Chemist, and Dr. Foster D. Snell, Consulting Chemical Engineer, have prepared four volumes designed for the person who wishes to train himself in chemistry. These four volumes contain a thorough knowledge of chemistry divided into these sections, The Theory of Inorganic Chemistry, Elements and Compounds in Inorganic Chemistry, Aliphatic and Aromatic Compounds of Organic Chemistry, and Chemicals of Commerce. Considering the opportunities in industry both now and after the war, these books make it easy to learn or review the principles of chemistry and their countless practical applications. The four volumes are cloth bound, illustrated, contain 1214 pages, sell at $7.95 for the set, and are published by D. Van Nostrand Co., Inc., 250 Fourth Ave., New York 3, N. Y.

Bag of Shot for Uneven Pressing*

Sometimes it is desirable to press a sticker or gummed label upon an uneven surface or to do similar pressing on uneven surfaces. There is hardly anything handier for this purpose than a small bag of fine shot. Mercury is better, but of course mercury is much more expensive and under high pressure may be forced out. Mercury can be held in a bag in about the same way as shot. When extreme pressure is wanted the bag of shot may be placed on the surfaces to be pressed with an additional weight on top. The pressure is then evenly distributed over the entire area, something that cannot be accomplished with a flat pressing surface or even with ordinary soft surfaces. A bag of shot kept about the desk or wherever pressing of this nature is done often comes in handy.

*Contributed by W. F. Schaphorst, M. E., Newark, N. J.

APPLICATION OF THE SLUDGE INDEX TEST TO PLANT OPERATION

By DON E. BLOODGOOD*
Assoc. Prof. of Sanitary Engineering
PURDUE UNIVERSITY

THE Sludge Index as given in "Standard Methods for Examination of Water and Sewage" has been a much discussed test. The original idea of the test was to indicate the bulking of activated sludge. The units used increase with an increase in the volume occupied by the same weight of solids. As a qualitative test it has been very helpful and a desire has often been expressed to correlate the sludge index with plant operation data.

If it is assumed that the concentration of sludge, obtained in the bottom of a cylinder, in a sludge index test, is the maximum concentration that can be obtained in a reasonable settling period, without detriment to the activated sludge, it is believed that the results can be used in a mathematical calculation which is applicable to plant operation.

It is realized, however, that the sludge index data obtained in a 30-minute settling period may not be the same as might be found for a 60-minute period (Fig. 1). It has been found from experience that even with mixed liquor which settles exceptionally well the concentration of sludge in the bottom of the test cylinder may be slightly higher at the end of 60 minutes than it is at the end of 30 minutes. The indications are that for mixed liquors of poor settling qualities the difference between the concentration at 30 minutes and 60 minutes is even greater. It would seem, therefore, that if the sludge index were calculated on a 60-minute settling period the results would be more satisfactory when used in the following calculations.

If the settling cylinder is considered as a secondary settling tank and the settled sludge as return sludge, the sludge index may be expressed in per cent solids of the sludge. Then per cent solids in the bottom of the cylinder may be obtained by dividing 100 by the sludge index. This relation may be seen in Fig. 2.

This graph would be of assistance in activated sludge plant operation if the only desire were to determine the maximum return sludge concentration possible as indicated by the sludge index determination. The matter of sludge solids balance, however, enters the considerations and it is necessary to take it into account in discussing plant operation problems.

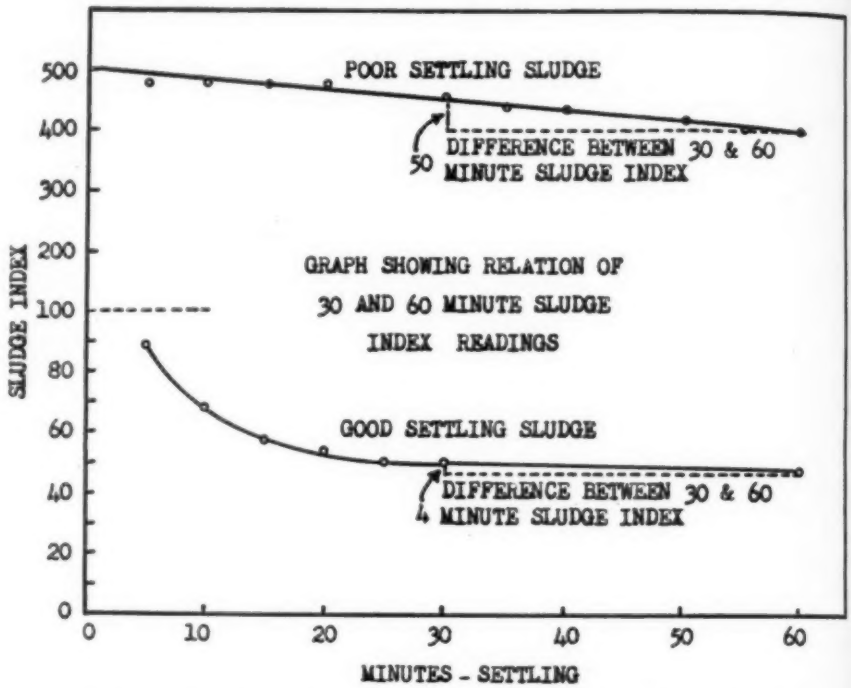


Fig. 1. Graph Showing Relation of 30 and 60 Minute Sludge Index Readings.

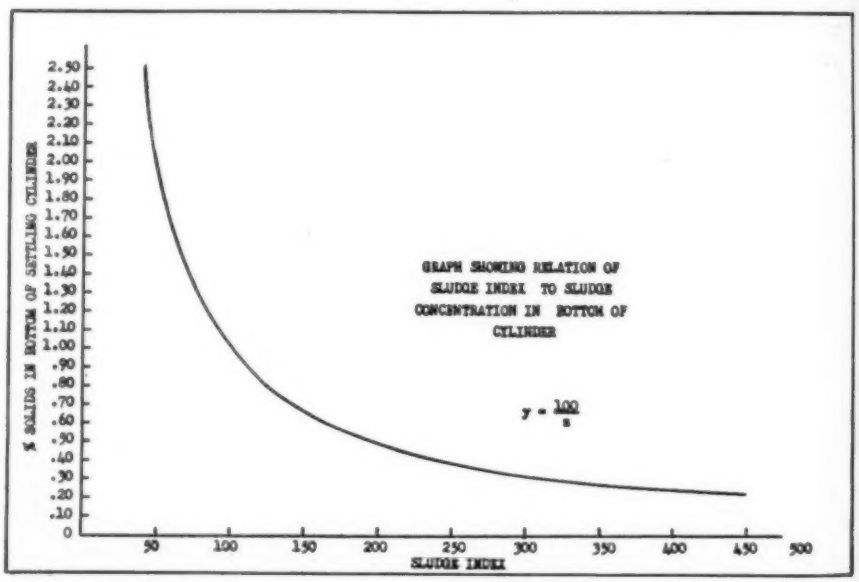


Fig. 2. Graph Showing Relation of Sludge Index to Sludge Concentration in Bottom of Cylinder.

*Formerly Supt. of Sewage Treatment, Indianapolis, Ind.

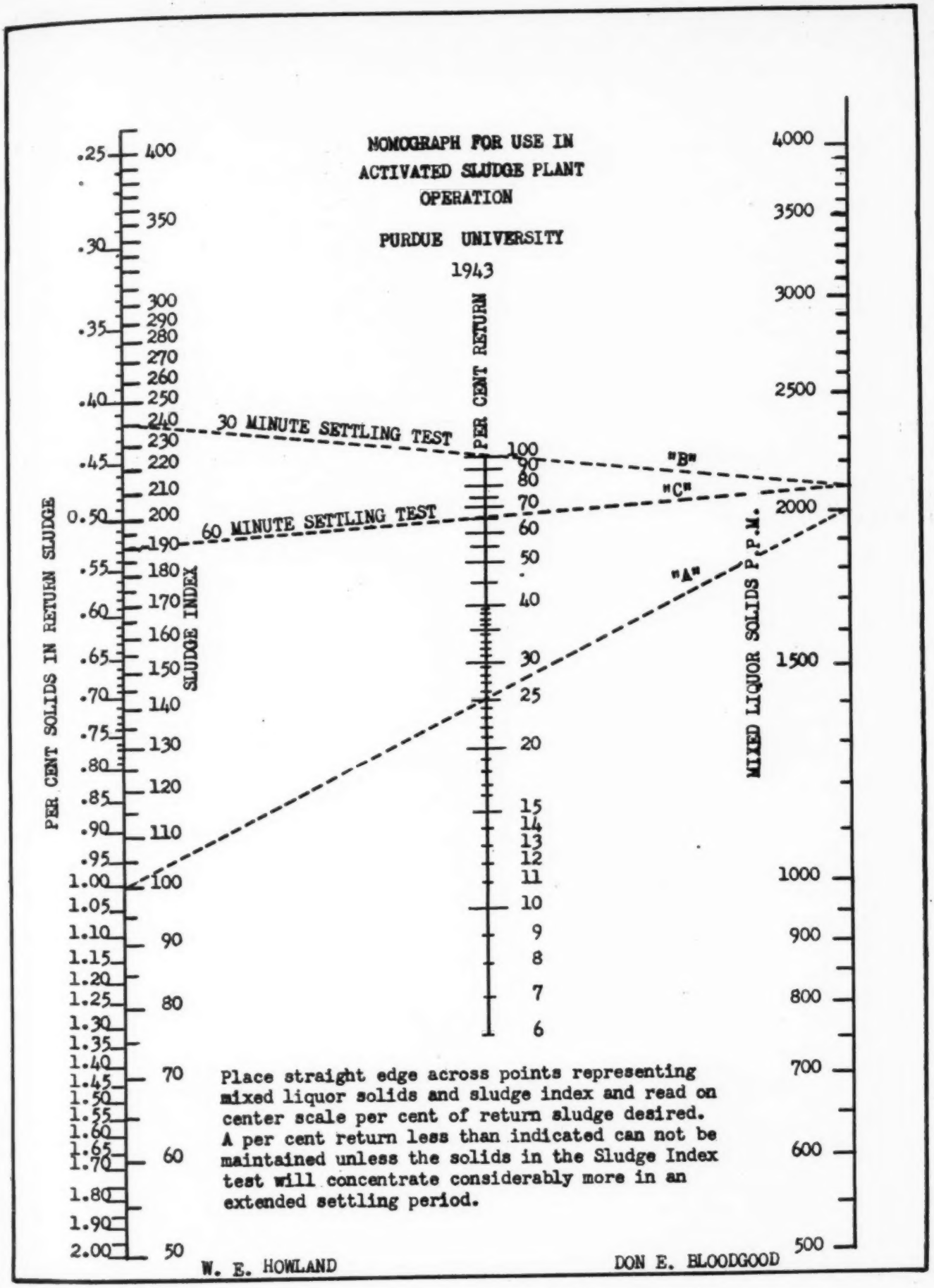

NOMOGRAPH FOR USE IN
ACTIVATED SLUDGE PLANT
OPERATION
PURDUE UNIVERSITY
1943
PER CENT SOLIDS IN RETURN SLUDGE
SLUDGE INDEX
PER CENT RETURN
MIXED LIQUOR SOLIDS P.P.M.
30 MINUTE SETTLING TEST
60 MINUTE SETTLING TEST
"A"
"B"
"C"
Place straight edge across points representing mixed liquor solids and sludge index and read on center scale per cent of return sludge desired. A per cent return less than indicated can not be maintained unless the solids in the Sludge Index test will concentrate considerably more in an extended settling period.
W. E. HOWLAND
DON E. BLOODGOOD

Fig. 3. Nomograph for Use in Activated Sludge Plant Operation.

Development of Formulae

In an analysis of the sludge balance, for any one day of activated sludge plant operation, it is quite evident that the amount of solids in the mixed liquor must be equal to the solids in the return sludge, assuming the waste sludge, incoming raw sewage solids and the loss of solids by oxidation are considered negligible quantities. The mixed liquor return sludge balance may be expressed by the formula:

$$(a + b)x = b\,(y) \quad \ldots\ldots (1)$$

a = sewage flow mgd.
b = return sludge flow mgd.
x = mixed liquor solids in %
y = return sludge solids in % (or solids in the bottom of settling cylinder)

If the sludge index be represented by (z), then, as above explained,

$$y = \frac{100}{z} \quad \ldots\ldots (2)$$

The per cent by volume of return sludge may be expressed by the formula:

$$m = \frac{b}{a} \times 100 \quad \ldots\ldots (3)$$

By simple algebraic substitutions of Formulae (2) and (3) in Formula (1) it may be written:

$$m = \frac{100}{\frac{100}{zx} - 1} \text{ or}$$

$$z = \frac{m}{(1 + .01\,m)x}$$

A Useful Nomograph

Based on calculations with Formulae (2) and (3), a nomograph has been prepared (Fig. 3) which may be of assistance in activated sludge plant operation. Assuming the conditions as indicated by line "A," Fig. 3, with a mixed liquor solids concentration of 2000 ppm and a sludge index of 100, it would be necessary to return 25 per cent by volume of return sludge of a concentration of 1.00 per cent. A higher per cent return could, of course, be maintained at an added return sludge pumping cost. On the other hand an attempt to return less than 25 per cent would mean holding the return sludge in the secondary tanks longer than seems advisable.

The assumed conditions as indicated by line "B," Fig. 3, with mixed liquor solids of 2100 ppm and a sludge index of 240 (calculated on the regular 30-minute settling period) indicates the necessity of returning 100 per cent. Any amount of return less than 100 per cent would mean a rapid filling of the secondary settlers with sludge, unless the calculated sludge index at the end of a one hour settling test should be materially less than for a 30-min. test as illustrated by the line "C" on Fig. 3. In this case if a rate of sludge return of 65 per cent were maintained, the solids balance would be correct.

Comments:

1. If it is agreed that activated sludge should not be held in the secondary settling tanks longer than one hour it might be well to extend the period of settling of the sludge index test to one hour instead of the present thirty minutes.

2. The per cent of return sludge necessary for proper plant operation depends upon the mixed liquor solid concentration and upon the sludge index.

3. The nomograph presented is helpful in applying the sludge index test to the control of activated sludge plant operation.

The writer is indebted to Dr. W. E. Howland for his assistance in the construction of the nomograph presented.

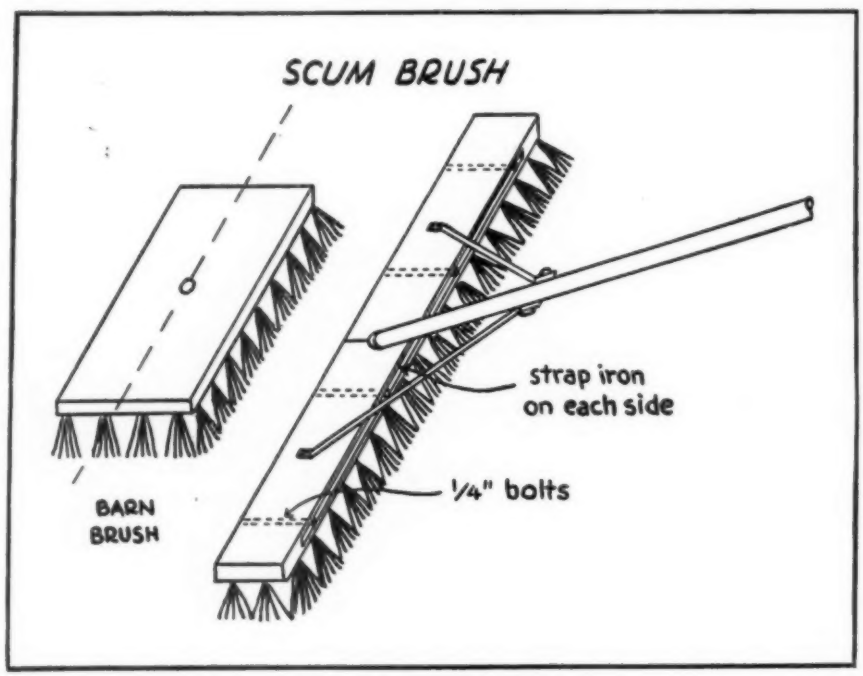
Scum Removal Brush for Settling Tanks*

Removing scum from clarifier tanks was mostly a hit and miss operation until we hit upon a device as shown in the accompanying sketch. Previously, scum removers had been made from solid boards on a handle or as an elaborate frame covered with mesh. The solid board brings over too much water and the mesh screen is hard to relieve of the scum.

The scum brush shown in the accompanying sketch overcomes several objections of other types of scum removers, carries little or no water with it, and may easily be relieved of its scum by a quick downward movement which sloughs off the scum.

In addition to the sketch, the following directions for making the scum brush are helpful. Procure a large barn brush about 5x15 in. and saw it through the middle as shown in line "AA." Now place these two pieces end to end and connect with two straps irons placed at the edge of the brush. Equip with a handle braced as shown, and the brush is all set to go. The bristles are long enough to go below the surface of the water and bring the scum with it as the brush is pulled toward the operator.

At Fennimore we never had a clean tank until we made and used the above brush.



Scum Removal Brush

*Contributed by Basil Miller, Supt. of Utilities, Fennimore, Wis.

BUILD YOUR OWN 20° INCUBATOR

By BARTLEY J. CASH
Asst. Supt.
Dept. of Water and Sewage
NEWNAN, GA.

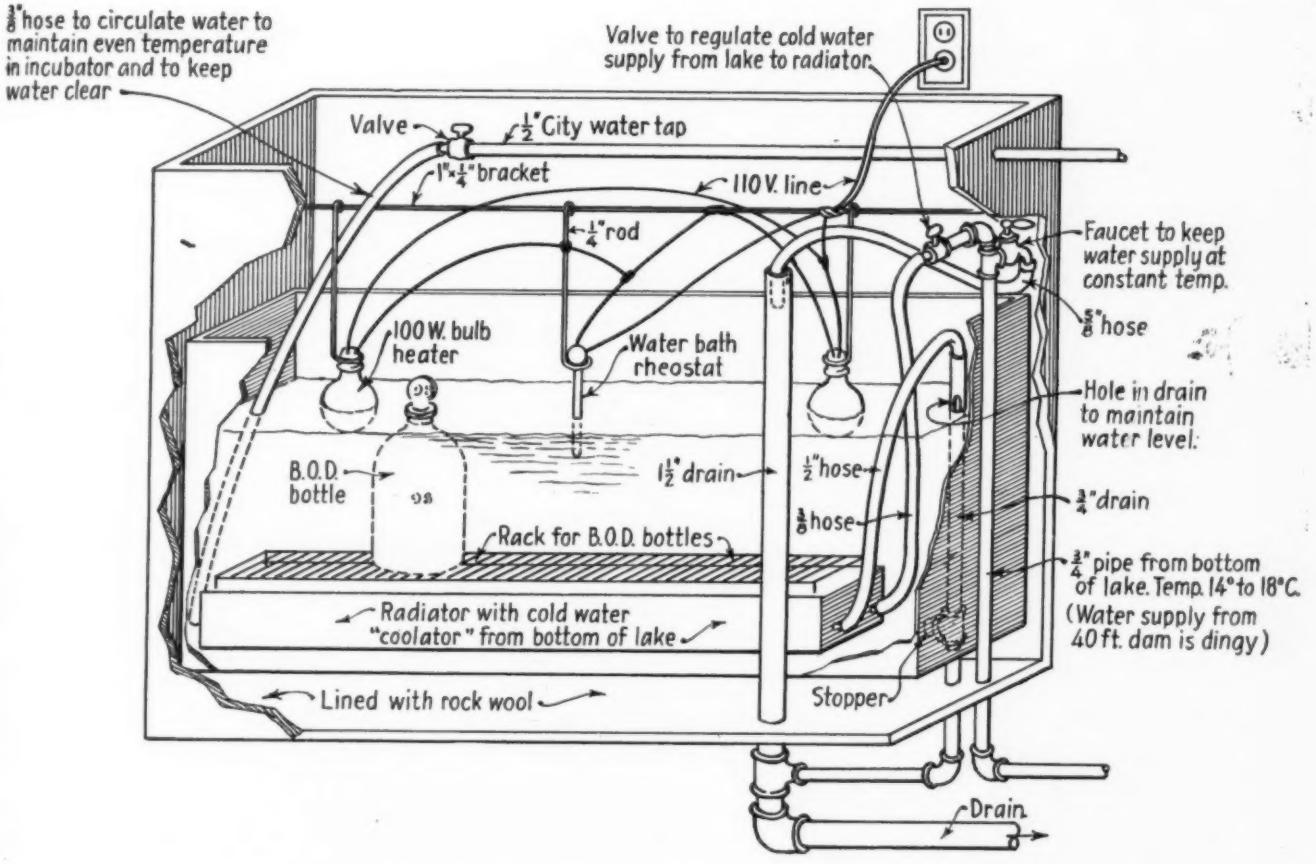
THIS is another "build your own if you can't buy it." This one is a 20° incubator built at our Newnan Laboratory for making the B.O.D. test on sewage. A vacant cabinet under the sink made an ideal place, as there was a drain and also a water tap from the city supply.

The tap water, as is shown in the drawing, is used as the water immersion bath. It is circulated to keep the water clear, and then passes out through a hole in the drain at the height of the bottles. The flow of city water through the bath is relatively slow.

The cooling water comes from the bottom of our dam, which is 40 ft. high. This water has a temperature of about 14° C. and is piped through a ¾-in. galvanized pipe about 3½ ft. under ground. Part of this cooling water is passed through the faucet to waste down the drain, just to keep it the same temperature, and the remainder is passed through the radiator coil at the bottom of incubator bath and then out the drain.

The cooling coil reduces the temperature of the water bath and it is necessary to add heater units. Two 100 W. 110 V. bulbs immersed in the bath serve as heater. To control the temperature an immersion type electric thermoregulator is used, having an operating range from 50 to 400 deg. F. with a sensitivity of 0.1° F. plus or minus.

With very little practice this bath can be regulated to the proper temperature, and it will give very little trouble. The design is shown in the accompanying sketch. It can be adapted to fit conditions.


⅜" hose to circulate water to maintain even temperature in incubator and to keep water clear
Valve to regulate cold water supply from lake to radiator
Valve
½" City water tap
1" × ¼" bracket
110 V. line
¼" rod
Faucet to keep water supply at constant temp.
⅝" hose
100 W. bulb heater
Water bath rheostat
Hole in drain to maintain water level
B.O.D. bottle
1½" drain
½" hose
¾" drain
⅜ hose
Rack for B.O.D. bottles
¾" pipe from bottom of lake. Temp. 14° to 18° C. (Water supply from 40 ft. dam is dingy)
Radiator with cold water "coolator" from bottom of lake
Lined with rock wool
Stopper
Drain

Home-built Incubator for B.O.D. Determinations.

OIL WASTE EXCLUSION FROM SEWERS

Baltimore Experiences

By C. E. KEEFER Prin. Ass't. Engr.
BUREAU OF SEWERS
BALTIMORE, MD.

IN 1927 a fire near the outlet of the largest storm drain in Baltimore resulted from the escape of gasoline and oil into the drain. Causing no serious damage, it did, however, result in passage of a city ordinance requiring daily storage of waste oil, crank case drainings, and greases in approved steel drums by all users of such materials.

The Baltimore Ordinance No. 1083

An ordinance to regulate the handling, storage, transportation and disposition of waste oils and greases resulting from the use, operation, cleaning, repairing or servicing of vehicles, machinery or appliances of any kind upon all premises in Baltimore City; providing for enforcement, and also providing a penalty for violation of the provisions of this ordinance.

Section 1. Be it ordained by the Mayor and City Council of Baltimore, That from and after the date hereinafter provided, the following rules and regulations shall apply to the handling, storage, transportation and disposition in the City of Baltimore of waste oils and greases resulting from the use, operation, cleaning, repairing or servicing of vehicles, machinery or appliances of any kind:

(a) All waste oils, including crank case drainings, shall be immediately taken up and deposited and kept while on the premises in steel drums, the character, size, construction, number and location of which shall be from time to time prescribed by the Board of Fire Commissioners of Baltimore City, or in containers of other construction approved by the Chief Engineer of Baltimore and by the said Board.

(b) All waste greases shall be collected at least once daily and deposited and kept as in the manner provided for waste oils in the preceding paragraph, and in no case shall any waste greases be permitted to remain in or about any premises over night, except when so deposited.

(c) All such drums, containers and their appurtenances shall be kept and maintained at all times in first class condition and tightly closed so as to prevent the escape of any of the contents thereof, and shall be used for no purpose other than the storage and transportation of waste oils and greases.

(d) The Mayor and City Council, acting through the Chief Engineer of Baltimore, shall determine from time to time the agencies by or through which all such drums, containers and/or the contents thereof shall be removed, stored, transported and disposed of, and the times when, the places where and the manner in which the same shall be done, and such determination shall be subject to the approval of the Board of Fire Commissioners of Baltimore City; and no such drums, containers and/or contents shall be removed, stored, transported or disposed of in any other manner or through any other agency.

Section 2. And be it further ordained, That this ordinance shall not be construed to prohibit the sale and/or reclamation of waste oils and greases, provided, on such sale and/or reclamation, said waste materials are otherwise handled, stored, transported and disposed of in accordance with the terms and provisions of this ordinance and any rules and regulations made in pursuance thereof.

Section 3. And be it further ordained, That terms used in this ordinance are hereby defined as follows:

The term "waste oils and greases" shall include all oils and greases which, by reason of previous use in and about vehicles, machinery or appliances of any kind, are in such condition as to be unfit for further use for such purposes without reclamation.

The term "premises" shall include all real and leasehold property where such vehicles, machinery, or appliances of any kind are used, operated, cleaned, repaired or serviced.

The Author

The term "person" shall include persons, firms and corporations.

Section 4. And be it further ordained, That any person violating any of the provisions of this ordinance shall be subject to a fine of Fifty Dollars ($50.00) for each and every offense.

Section 5. And be it further ordained, That the Board of Fire Commissioners of Baltimore City are hereby charged with the duty of enforcing the terms of this ordinance.

Section 6. And be it further ordained, That all ordinances, or parts of ordinances, inconsistent with the provisions of this ordinance be, and the same are hereby repealed to the extent of such inconsistency.

Section 7. And be it further ordained, That in the event that any word, phrase, clause, sentence or section of this ordinance shall be declared invalid by any court, the remainder of the ordinance shall not be affected thereby, but shall remain in full force and effect.

Section 8. And be it further ordained, That this ordinance shall take effect three (3) months after the date of its passage and approval.

Approved May 11th, 1927.
HOWARD W. JACKSON, Mayor.
Attest: A True Copy:
JOHN A. SLOWIK, City Librarian.

Collection Contracts

In order to provide for the collection of these materials the city entered into a two-year contract with a collection company. Since the first contract expired, Sept. 30, 1929, the work has been done by three companies at different times. The cost to the city is shown in the accompanying table.

During this sixteen year period 4,287,714 gallons of oil and greases have been collected. This is equivalent to 263,860 gallons yearly at an average cost of 7.5 mills per gallon.

The contractor is required to furnish steel drums for the storage and transportation of oil and greases where the amount collected is more than 20 gallons weekly. For lesser quantities, the containers are furnished by those who must dispose of the oil or grease. Containers must be collected within 24 hr. after they are full.

The present contractor has three 1000-gal. tank trucks for the transportation of the materials. Each truck is equipped with a suction and a discharge pump for handling the oils.

Oil Purification Plant

Oil is discharged from the tank truck into an underground storage tank, from which it is pumped into a 2000-gal. dehydrating tank, containing steam coils. Moisture evaporation is accomplished by passing steam at 90 lb. pressure through the coils for a period of five to eight hours.

Dehydration is followed by sulfuric acid treatment in a 1500 gal. storage tank. Sludge precipitated from the oil is disposed of in a lagoon. Clay is added to the partially purified oil which is then cooked with steam at about 600 deg. F. for eight to ten hours. During the cooking the higher volatile hydrocarbons such as kerosene, naphthalene, and the alcohols are distilled off for use as fuel in the steam generating plant.

The oil residue is cooled to approximately 200 deg. F. and filtered in a Shriver plate press, producing a filtrate equal in quality to new oil and ready for sale. About 12 hours are required to complete the process.

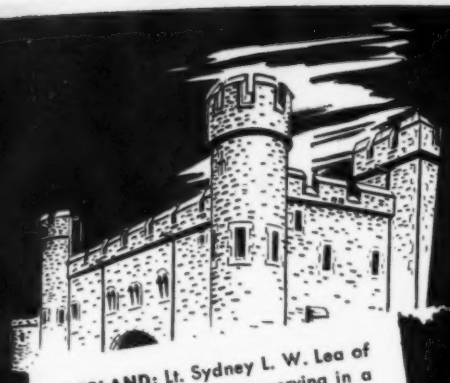
The collection and purifying of oil is not unique with Baltimore as similar plants are in operation in New York City, Philadelphia, and elsewhere. The unique feature about the practice is that Baltimore has adopted an ordinance requiring daily collection and disposal of greases and oils and has made the necessary provision for having the work done. Since this ordinance has been in effect the sewers in the city have been remarkably free from inflammable materials.

COST OF COLLECTING GREASE AND OIL IN BALTIMORE FROM 1927 TO 1943

Year	Contractor	Amount paid contractor	Grease and oil collected, gal.
1927	Provident Oil Service Co.	$ 810	71,701
1928		3,240.00	265,000
1929		3,037.50	318,000
1930		2,430.00	286,850
1931		2,430.00	280,100
1932	Thomas Leonard	2,422.50	229,299
1933		2,400.00	139,804
1934		2,400.00	143,280
1935		2,300.00	155,690
1936		2,000.00	169,515
1937		2,000.00	156,150
1938		1,625.00	120,940
1939	City Waste Oil Co.	500.00	327,440
1940		500.00	437,420
1941		768.75	473,420
1942		1,575.00	416,099
1943		1,575.00	297,006
	Total	$32,013.75	4,287,714

Penn Salt men in the service meet a Penn Salt product in the service . . .

Perchloron



ENGLAND: Lt. Sydney L. W. Lea of Sales found Perchloron serving in a foot bath.

U. S. A.: Sgt. Arthur F. Bixby of Heavy Chemical Sales found Perchloron in use at two camps in different states.

SOUTH ATLANTIC: George J. Craig, Jr., SK 3/c of Accounting, found Perchloron serving advance naval bases.

U. S. A.: Captain Charles B. Griffin, Jr., of Technical Service found Perchloron serving several different camps and arsenals.

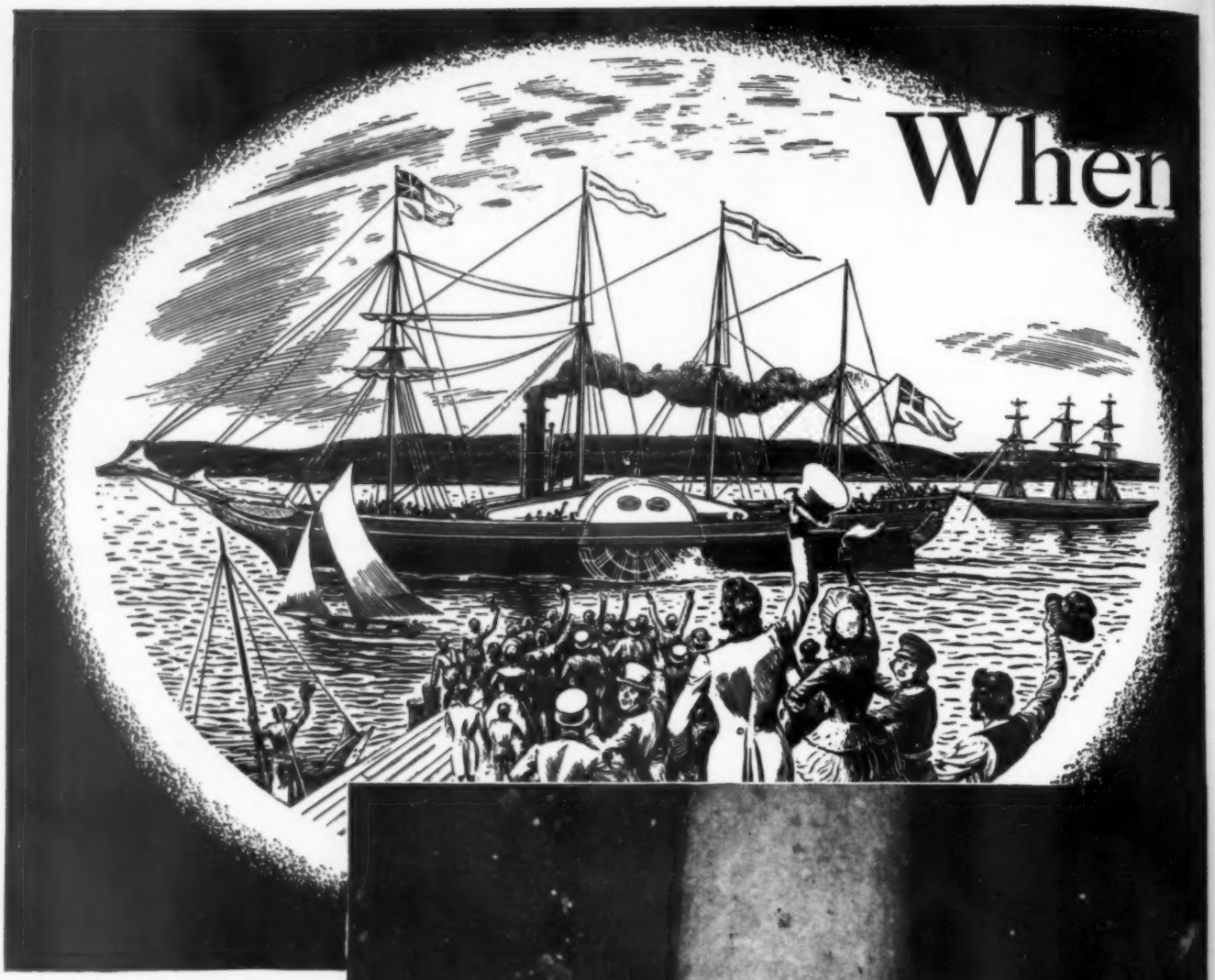
AUSTRALIA, NEW GUINEA: Major George D. Grogan of Heavy Chemical Sales found Perchloron used for various sanitizing purposes.

FLORIDA: Pvt. Edward F. Smith, Jr., of Laundry & Dry Cleaning, found Perchloron in use in mess halls, kitchens, foot baths.

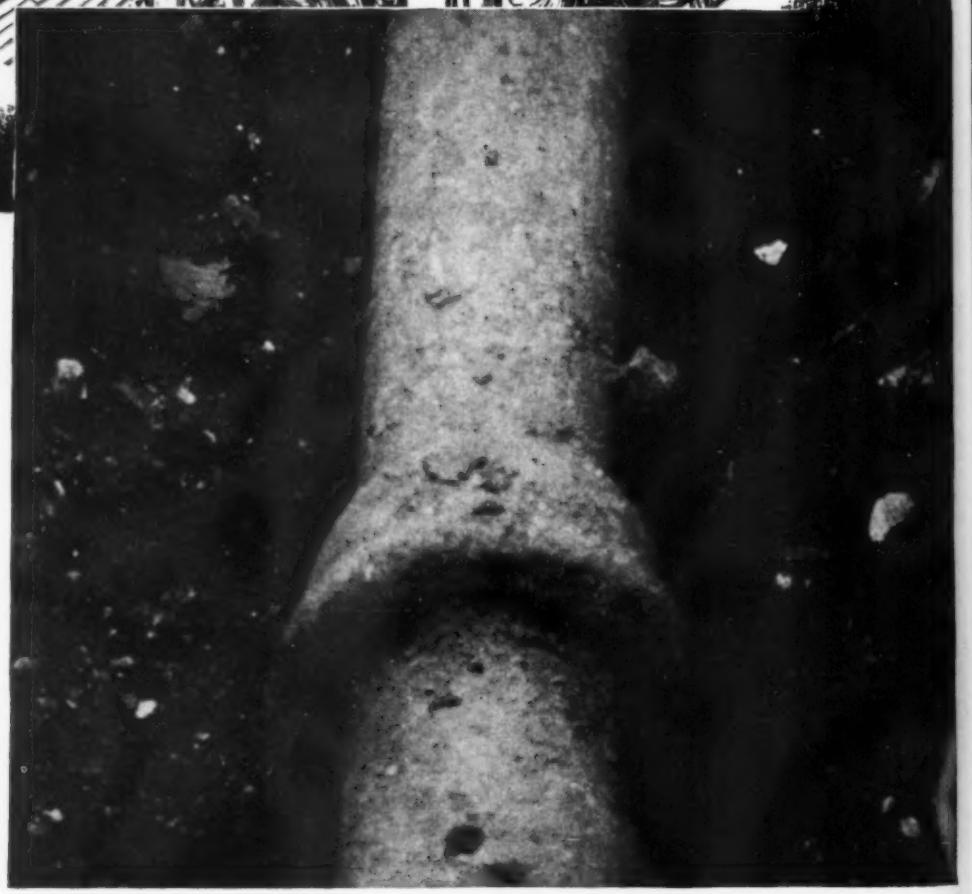
OKLAHOMA: S/Sgt. T. Bayard Grace of Purchasing found Perchloron on duty.

In camp kitchens, laundries, shower rooms, foot baths, Per*chlor*on is doing important work . . . sanitizing the water supply for the army and navy.

Per*chlor*on is again available for civilian use . . . in limited quantities. You can depend on it to serve your water sanitation problem as effectively as it serves the armed forces. Call on a Penn Salt representative for advice and co-operation without obligation. Write today for *free* Per*chlor*on booklet to Dept. WWS.



When the steamship Great Western *arrived in New York harbor from Bristol, England, more than a century ago, establishing steam navigation across the Atlantic, this cast iron water main began its long service to the citizens of St. Louis. Unretouched photograph at right show a section of this old main uncovered for inspection.*



St. Louis, Mo., **installed this cast iron water main more than a century ago. Twenty years later it was taken up and removed to its present location where it has been in service ever since.**

the first steamship crossed the Atlantic–

St. Louis laid a cast iron main which is still in SERVICE . . .

Charleston, S. C. This cast iron main is still functioning after 106 years of continuous service.

Lynchburg, Va. This 115-year-old main, still in service, is the second-oldest cast iron water main in America.

THE late Justice Holmes once said that "a page of history is worth a volume of logic." In this advertisement are shown unretouched photographs of cast iron pipe, in service in the ground, temporarily uncovered for inspection, which have a history of 100 years or more of continuous service.

Why are pipe materials other than cast iron generally referred to as substitutes for cast iron? Because cast iron pipe is the *standard* as well as the *only* material for underground mains with a history of long life—a century or more in this country—two centuries or more, abroad.

But, far from resting their case on history alone, the makers of cast iron pipe can point to outstanding accomplishments in product development. The production of cast iron pipe today is on a scientific basis with laboratory controls at every step from raw materials to finished pipe. So, whether you are laying cast iron pipe now, or specifying it now for post-war construction, you can be sure it will not only live up to its history, but improve on it.

CAST IRON

Cast Iron Pipe Research Association
Thomas F. Wolfe, Research Engineer, Peoples Gas Building, Chicago 3

CAST IRON PIPE
SERVES FOR CENTURIES

RUGGED

EFFICIENT

DEPENDABLE

ZECO GREENSAND ZEOLITE

ZECO and HI-ZECO Greensand and Zeolite for water softening, filtration and iron removal. ZECO Manganese Zeolite for iron and manganese removal. COREXITE mineral for corrosion control and water stabilization.

"BUY MORE ★ WAR BONDS"

ZEOLITE CHEMICAL CO.

Sales Office
140 Cedar St., New York, N. Y.

Factory
Medford, N. J.

Pioneer Producer of GREENSAND ZEOLITE MINERAL

SEWER DESIGN PRACTICES

Currently Prevailing in the United States

By W. L. MALCOLM
Director
SCHOOL OF CIVIL ENGINEERING
CORNELL UNIVERSITY, ITHACA, N. Y.

THIS paper does not purport to advance any new theory of design nor to advocate any special method now in use, but proposes simply to show trends that designers in the municipal field are making or that state or municipal authorities are requiring in the field of sewer design.

In order to obtain first-hand knowledge of present points of view it was necessary to obtain definite replies to certain questions, on which it was thought there might be difference of opinion. A questionnaire was sent to a large number of consulting engineers, civic authorities, and state officials. The questionnaire was quite inadequate to cover the entire design field, but in these busy times it was considered expedient to keep it short in order to secure a larger number of replies.

The number of persons written to and the number of answers received are shown in Table 1.

The Author

TABLE I

Questionnaires

	No. Sent	States Represented	No. Replies	States Represented	% Replies	% States
Consulting Engineers	47	18	27	11	57	61
Civic Authorities	185	44	86	38	46	86
State Offices	48	48	31	31	65	65
Total	280	..	144	..	51.5	..

In these times when personnel is depleted this result is considered excellent. Since the replies were very widespread it is believed that the answers will be truly representative of nation-wide practice.

Background

What are commonly called today "sewerage systems" should in reality be called water carriage systems since the fouled water from domestic and manufacturing use is used as the transportation vehicle to carry away the solids as well as the liquids.

These water carriage systems are two in number: (1) The separate system, (2) The combined system. In the former the domestic sewage, so called, is carried in one net-work of pipes called the sanitary or domestic sewers, while the storm water is carried in another called storm sewers. In the combined system the domestic sewage and the storm water are carried in the same pipes.

In this paper no attempt is made to set forth the advantages and disadvantages of either of these systems. The prevailing practice at the moment is that of providing separate systems. This practice is followed primarily because of the sewage treatment problem and partly because the costs to treat all the rainfall as well as the domestic sewage are not bearable by municipalities. It must be noted however that cities already with combined sewers will have to continue with the system.

Inasmuch as the domestic sewage has at its maximum a volume very much less (some authorities give 2 per cent) than that of the storm drainage, it has been customary in the design of combined sewers to design them for the storm water only. No information is available to show that there is any trend away from this custom and consequently the assumption will here be made that this is the continued practice.

The problem thus reduces itself to two phases:

A. The design of domestic or sanitary sewers.

B. The design of sewers to carry storm water.

A. On the Design of Domestic Sewers

The design must naturally be made so that the sewer is large enough to carry all the liquids and solids that reach it at such velocity, as will prevent the solid particles from depositing or stranding.

Volume of Domestic Sewage

The volume of water that reaches the sewer is, in part at least, a direct result of the utilization of the domestic water supply. In sewer design, however, interest is not in total flow, but in rates. It used to be more or less the rule that a fair estimate of the maximum rate of water consumption of municipalities would be about three times the average yearly rate.[1] Then since there was retardation in the use of water in households, manufacturing, etc., the discharge into the sewers would be a little less than this high rate. The figure commonly quoted for sewage flow was twice the average yearly rate of water consumption.[2] It is understood that water for manufacturing purposes, obtained from private supplies, would add to this quantity and would have to be computed wherever it occurred.

Ground Water

The amount of ground water that finds its way into sewers should also be given consideration. Designers have used "so many gallons per mile of sewer" or "gallons per acre."

Velocity

Domestic sewers should be laid on sufficient slope to prevent deposits, particularly of organic matter. The velocity necessary has always been an essential problem.

Since most domestic sewers are comparatively small, they are usually made of circular pipe.

Circular sewers have the same hydraulic radius regardless of whether flowing full or half full, therefore the velocity is the same at these depths. The maximum dis-

Ed. Note: Most of the material appearing in this paper was also presented by the author before the Canadian Institute on Sewage and Sanitation in a review of sewer design practices.

charge occurs when the sewer is flowing about eight-tenths full. For many years it was claimed that domestic sewers should only flow half full in order that proper ventilation might be maintained at all times.[2]

With these ideas in mind it was thought that the questionnaire should request answers to four questions.

(1) What is the minimum velocity to be used?

(2) What percentage, if any, should be used in calculating the maximum rate at which municipal water was returned to the sewers?

(3) Should domestic sewers be designed to flow full or half full?

(4) Should provision be made for ground water.

Results of Questionnaires

The results are tabulated in Tables II to VI inclusive.

Conclusions on Domestic Sewer Design

From the foregoing tabulations the following conclusions appear logical.

(1) If the average water consumption can be obtained the maximum flow of domestic sewage may be obtained by using a factor between 1.0 and 2.0 of the water supply. Apparently the authorities agree that a considerable amount of judgment is necessary in the individual cases.

(2) For minimum flow requirements some state officials apparently prefer to set down certain minimum requirements based on gallons per capita per day. Viz., New York, 400 gpcpd. for laterals, and 250 gpcpd. for mains. Minnesota has the same rule; New Jersey requires 20 gals. per lin. ft. of sewer per day. Alabama, Illinois, North Dakota, Oklahoma, Oregon have somewhat similar provisos. Seven of the states replying have no requirement at all. It would appear that there is perhaps a very slight trend toward state requirements of this nature.

(3) As regards infiltration, each engineer or official evidently bases his reply on his experience. It is noted that thirty-five municipalities require provision for infiltration; twenty-five do not; fifteen provide it where necessary.

Three engineers provide for infiltration; one depends on joint tightness, and nineteen provide it when necessary. This is logical as the consulting designer has a wider field to view than the municipal official.

The state authorities hold similar views to those expressed by the consulting engineers.

(4) Concerning minimum velocities, from Table IV it is quite evident that two feet per second is the minimum velocity at which the majority of designers aim.

This is in conformity with the report of a committee of the Boston Society of Civil Engineers—to study limiting "velocity of flow in sewers."[3]

(5) Regarding design depth of flow, it appears that forty-two state that sewers should be designed to flow half full, eleven at or about the depth for maximum discharge (8/10ths full), and sixty-seven design to flow full. It would appear that the present trend is to design for full depth of pipe.

It is apparent, of course, that after sewers fill to capacity air must be drawn into the sewer when this flow passes. Thus each day there must be inflow and outflow of air in addition to the normal flow. This should be ample to provide for ventilation.

TABLE II
Design Requirements for "Q"
Factors for Use of Water Records to Obtain Sewage Flow

	Below 2	2	2.5	3	Above 3	No Requirement
Consulting Engineers	2	3	5	1	0	..
Civic Authorities	21	9	0	3	2	..
State Authorities	8	3	1	1	1	7
Total	31	15	6	5	3	7

TABLE III
Design Requirements for "Q"
Gals. Per Capita Per Day

	Below 100	100	200	250	300	400	Varied
Consulting Engineers	..	..	1	..	..	1	3#
Civic Authorities	4	14	2	..	7	2	6
State Authorities	..	1	1	2*	..	2*	..
Total	4	15	4	2*	7	5	9

*New York requires 400 for laterals 250 for mains.
#One uses M = 500/P/½.

TABLE IV
Infiltration Provided For

	Yes	No	If Local Situation Requires
Consulting Engineers	3	1	19
Civic Authorities	35*	25	15
State Authorities	3	2	15
Total	41	28	49

*15 give quantitative requirements from 10,000 gals. to 40,000 gals per mile; from 1,000 to 1,500 cu. ft. per acre; from .001 to .015 cu. ft. per acre per day.

TABLE V
Minimum Velocities in Domestic Sewers

	Velocities in Feet Per Second			
	Below 2.0	2.0	2.5	Above 2.5
Consulting Engineers	2	20	3	1
Civic Authorities	3	40	16	1
State Authorities	1	21	3	2
Total	6	81	22	4

TABLE VI
Flow Depths in Diameters

	½	¾	1.0	No Requirement	Vary
Consulting Engineers	7	3	12	..	1
Civic Authorities	21	7	47	..	6
State Authorities	14	1	8	7	..
Total	42	11	67	7	7

B. On the Design of Storm Sewers

As noted previously this discussion will cover the design of combined sewers as well as purely storm water conduits. No attempt will be made herein to consider the shape of the sewers or their hydraulic properties. Further, the areas are small compared with those of large watersheds, and hence the flows will vary much more rapidly.

Finally it is usual to consider that the rainfall is uniform over the entire area.

Background:

Early in storm sewer design it was often customary to design for specific intensities, those intensities continuing for a specific time. With the advent of more scientific measur-

ing devices this was found to be inadequate. Certain municipalities by measuring the rainfall in detail and the corresponding run-off obtained equations connecting these parameters. Thus there arose the era of empirical formulae.

Kuichling in 1889[4] advocated a reasoned approach to the problem. This has come to be called the Rational Method of Storm Water Sewer Design. Briefly it may be put in algebraic form:

$$Q = CIA$$

Where Q = rate usually in cu. ft. per sec.
C = run off coefficient.
i = intensity of rainfall—continuing for a time period equal to the time for the water after falling at the most distant point to reach the point under consideration.
A = acres of the contributary watershed.

Variations or modifications of the Rational Method have been advanced and advocated from time to time. Among these has been Ogden's suggestion[5] that Kuichling's Rochester data showed a straight line relationship between the population per acre and the coefficient "c."

Then Grunsky suggested[6] that attention should be given to storage on the ground and in the sewers. A fuller discussion of these varied methods is given in a paper by the author.[7] For a more exhaustive discussion the reader is referred to American Sewerage Practice, Vol. I by Metcalf and Eddy.[8] The problem of storage underlies the basis of design in the present U. S. Army airport requirements for runways.[9] Provision by this method obviously is not made for the sewers to be large enough to take all the rainfall *immediately* it reaches the inlets.

Questionnaire

The matters that have appeared somewhat controversial have been:

(1) The use of empirical formulae.

(2) The use of the "rational method" in any of its variations.

If the rational method was employed there arose the question of rainfall data, i.e., durations and intensities and the relationship between them. If the data could not be obtained locally, what was done about it? Should different rainfall curves be used in designing laterals and main sewers? Was there any relation between classes of areas and run off?

Again the question of the size of the questionnaire had to be considered. It was therefore cut to the few questions shown in the questionnaire in Appendix I hereto.

Answers to Questionnaire

Table VII shows the number who state whether they use the empirical or rational method of approach.

Of those who stated that they used the rational method, one consulting engineer says "sometimes"; and one says "partly"; two municipalities state "partly"; two use rational method as a check.

To the question of run off factors, Table VIII shows the answers.

TABLE VII

Number Using Empirical Formulae vs. Rational Method

	Using Emp. Form.	Using Rat. Meth.	Using Freq. Curves	No Freq.	Vary
Consulting Engineers	2	20	18	3	5
Municipalities	15	61	44	6	6
Total	17	81	62	9	11

TABLE VIII

Number Using Run-off Factors "C" in Rational Method

Areas*	1	2	3	4	5	6
Consulting Engineers	14	14	15	15	15	15
Municipalities	70	70	70	70	70	70
Total	84	84	85	85	85	85

*AREAS—Legend in Table VIII.
1—Rural, 2—Partly Built, no Paving, 3—Good Residential, 4—Crowded Residential, 5—Commercial, 6—Business.

Conclusions on Storm Sewer Design

The answers indicate clearly certain trends.

(1) It is evident from Table VIII that the profession is using the "Rational Method of Sewer Design" more and more.

(2) To the question as to how the rainfall curves were deduced mathematically the replies were disappointing. A few stated that the curves were set by eye. A very few advised the curves were worked out by the probability method. But the great majority did not even suggest how the curves were deduced. No conclusion can therefore be reached thereon.

(3) To the question where data could be obtained on rainfall if none were available locally, the following answers were received: seven would refer to Yarnell[10], nine would refer to the nearest weather bureau or city with data, one to Metcalf and Eddy[8], one to Davis.[11]

(4) Most consulting engineers and municipalities state they use frequency curves, but select a frequency curve of five, ten, or fifteen years as an over all curve for use throughout the entire area. As noted in Table VII only a very few use different frequencies for laterals, submains, and trunks. Most replies indicated that the frequency selected in any case should be determined by a study of the economics. A balance between the cost of the complete removal of the storm water (i.e., public convenience) and the cost of construction should be made. Table IX shows the answers of a very few who gave arithmetical data. This shows opinion to be divided, but the tendency is to use an over all rainfall curve frequency of five to ten years.

(5) The greatest difference of opinion lies in the evaluation of the "run off" ("imperviousness") factor.

From the answers given, the following data has been collected.

Area	"C"
Rural Areas	0.05 to 0.5
Partly Built-Up Unpaved Areas	0.2 to 0.75
Good Residential Areas	0.35 to 0.85
Crowded Residential	0.35 to 0.80
Commercial	0.5 to 1.00
Business	0.5 to 1.00

There does not seem to be any unanimity of opinion or does there seem to be any trend. It might be suggested that a study of Ogden's "population-run off coefficient" curve based on Kuickling's data might help reconcile the very varied opinions expressed.[4]

Practically no state makes provision in its State Health Department requirements for storm sewer design. Consequently in the data, tables, or discussion given no mention is made of state requirements.

TABLE IX

Rainfall Frequencies

	5-Year	Over 10-Year	All 15-Year	15 or More
Consulting Engineers	2	2	..	..
Municipalities	8	6	2	..
Total	10	8	2	..

APPENDIX I

Sewer Design Questionnaire

Storm Sewer Design

1. Have you an empirical rule for the design of sewers in your locality? If so, please give.
2. Do you employ the rational method of storm sewer design?

Rainfall Curves

3. After collecting data what mathematical method do you use for determination of rainfall curve?
4. If rainfall data for any particular area is not available, what information would you use?
5. Do you use frequency curves for rainfall?
   Wherein do you use frequency curves rather than an overall maximum one?
6. Are different frequency curves used in designing laterals, submain, trunk and intercepting sewers?
7. Do you use run off factors? If so, what factors do you use for rural areas?
   Partly built up—no paving.
   Partly built up—but paved—good residential.
   Crowded residential.
   Commercial.
   Business.

Sanitary Sewer Design

8. What velocity do you regard as the minimum for "self cleansing?"
9. What factor do you use to obtain maximum "domestic sewage flow" from the average per capita per day water consumption?
10. In designing domestic sewers—do you design for maximum flow filling (i) half the pipe?
    (ii) the whole pipe?
11. Do you make allowance in every case for infiltration or do you determine ground water table and make allowance when it rises above the sewer?

Location Date Signature

REFERENCES

1. Turneaure and Russel—Public Water Supply.
2. Staley and Pearson—The Separate System of Sewerage.
3. Journal Boston Soc. C. E.—Report of Committee, Oct., 1942, p. 286.
4. Kuichling—Trans. Am. Soc. C. E. Vol. XX, p. 1.
5. Ogden—Sewer Design.
6. Grunsky—Trans. Am. Soc. C. E. LXV, 1909, p. 294.
7. W. L. Malcolm—Ontario Land Surveyors An. Report, 1935, p. 187.
8. Metcalf and Eddy—American Sewerage Practice. Vol. I.
9. U. S. Aviation Engineers—Technical Manual—T.M.—5-255.
10. Yarnell—U. S. Department Agriculture—Bulletin 204.
11. Davis—Handbook of Applied Hydraulics. (McGraw-Hill, 1943).

How to Avoid Galvanic Corrosion

Galvanic corrosion is caused by two dissimilar metals in contact with a liquid capable of conducting an electric current. One of the metals or alloys is more soluble in the liquid than the other. Through its tendency to pass into solution an electric current is produced and takes away with it the more soluble (less noble) metal which passes into the solution as ions. In truth this phenomena is that of the wet-cell of old which was employed to produce direct electric current. The greater the difference in solubility of the two metals exposed to the liquid (electrolyte) the greater the current flow and the more rapid the galvanic action and corrosion of the weaker metal. The direct connection of dissimilar metals or their connection by a conductor, such as the wall of a steel tank, is known as a galvanic couple and unless one or the other of the two metals is effectively insulated galvanic corrosion to various degrees ensues.

Metals are classified in a galvanic series such as the accompanying table represents.

The most soluble and easily corroded metals are at the top of the list and the least corrodible are at the bottom. The farthest apart the metals are in the list the greater will be the galvanic action and corrosion rate to the weaker metal. The closer together the two metals in the series are the least the galvanic action between the two. Therefore a connection between zinc or aluminum and copper or red-brass would result in marked galvanic corrosion attack, whereas copper to lead or nickel would produce far milder galvanic corosion.

Position of Metals in the Galvanic Series

Corroded End (anodic, or least noble)

Magnesium
Magnesium alloys
—
Zinc
—
Aluminum 2S
—
Cadmium
—
Aluminum 17ST
—
Steel or Iron
Cast Iron
—
Chromium-iron (active)
—
Ni-Resist
—
18-8 Stainless (active)
18-8-3 Stainless (active)
—
Lead-tin solders
Lead
Tin
—
Nickel (active)
Inconel (active)
—
Brasses
Copper
Bronzes
Copper-nickel alloys
Monel
—
Silver solder
—
Nickel (passive)
Inconel (passive)
—
Chromium-iron (passive)
18-8 Stainless (passive)
18-8-3 Stainless (passive)
—
Silver
Graphite
Gold
Platinum

Protected End (cathodic, or most noble)

The following precautions are in order if galvanic corrosion is to be held to a minimum.

1. Select combinations of metals as close together as possible in the galvanic series.

2. Avoid combinations where the area of the less noble material is relatively small.

3. Insulate dissimilar metals wherever practical. If complete insulation cannot be achieved, anything such as paint or plastic coatings at joints will help.

4. Apply coatings with caution. For example, when painting—do not paint the less noble material without also coating the more noble, otherwise greatly accelerated attack may be concentrated at imperfections in coatings on the less noble metal. Keep such coatings in good repair.

5. Prevent or limit aeration of the corrosive liquid as much as possible to sustain the polariziing effect of the hydrogen film which forms on bare cathode surfaces.

6. If practical, add an appropriate chemical inhibitor to the corrosive solution.

7. Avoid using threaded connections to join metals well apart in the series, as the threads will probably deteriorate excessively. Brazed or welded joints are preferred.

8. Whenever possible, install relatively small replaceable sections of the less noble material at joints and increase the thickness of the less noble material in such regions.

9. Install pieces of bare zinc or steel to provide a counteracting effect to suppress the unwanted galvanic corrosion.

86 Firms to Exhibit at Milwaukee

At the A.W.W.A. Wartime Conference being held this month in Milwaukee 86 member firms of the Water and Sewage Works Mfrs.'s Assn. will be represented in the Exhibit Hall. So marked was the demand for exhibit space that the allocations had to be restricted to one exhibit space per applicant, so the number of firms to be represented was restricted to the 86 available spaces on the basis of first come first served.

This fact, together with the recorded hotel reservations, points to a new record in attendance for A. W. W.A.'s annual meetings.

BUILD YOUR OWN

By BERNARD ROWNTREE
Manager
CARMEL SANITARY DISTRICT
CARMEL, CALIF.

Sludge Pump Indicator

Very often something gets caught under the valves of plunger type sludge pumps. When this happens the pump may operate a long time before the operator knows it is not pumping sludge, unless he climbs to the top of the primary digester and observes the sludge flowing into it.

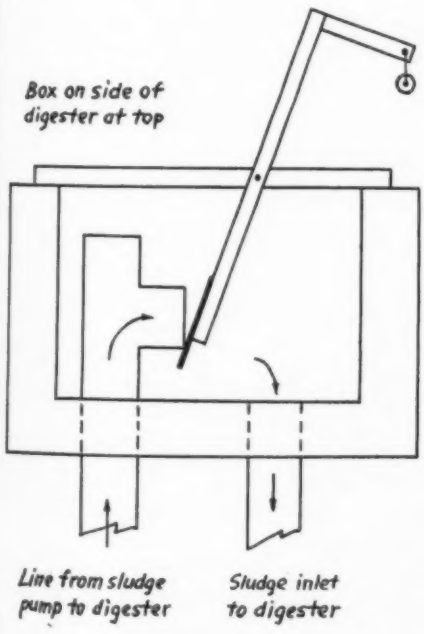
A simple device that shows when the sludge is flowing or being pumped is here sketched. It is assumed that the operator can see the top of the primary digester from some point near the sludge pump.

The pulsations of the sludge caused by the pump piston causes the indicator arm to move back and forth as the sludge is being pumped.

Gas-Storage Indicator

At plants having digesters with floating covers, and where all the gas required is not always produced, it is of interest to the operator to know how much gas he has in reserve so as to know how to adjust the gas burner.

The accompanying sketch illustrates a simple device that reveals the elevation of the floating dome and the approximate amount of gas in storage.



Sludge Pump Indicator

Gas production is the best indicator which the non-technical operator has as to the condition of the process of digestion going on in the primary digester.

Thermometer-Well for Digesters

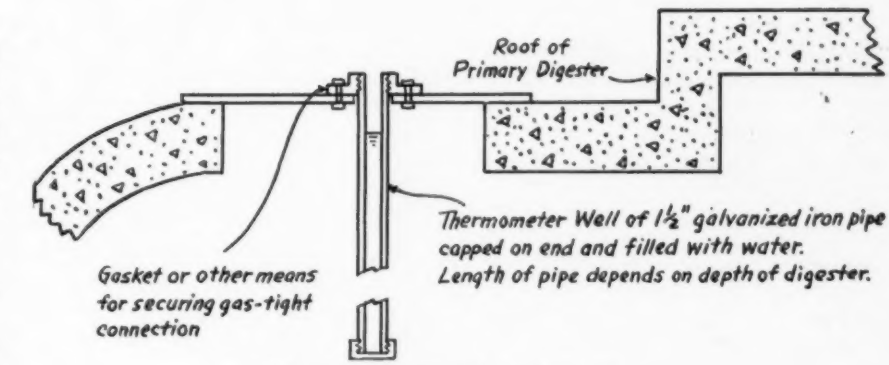
Every operator has learned by trial and error what is the best temperature at which his primary digester functions. The common method of taking the temperature is to hold a thermometer in the sludge stream flowing from the primary to the secondary digester.

This is not satisfactory as the temperature of the outgoing sludge may not be the same as that of the inside of the primary digester. Also the ordinary thermometer will start to cool off as soon as removed from the sludge for reading.

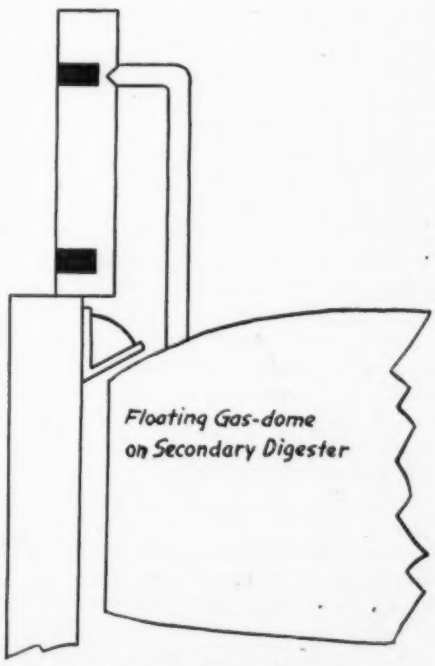
The accompanying sketch shows a thermometer well which consists of a pipe inserted through the top of the primary digester, the length of the pipe being determined by the lowest point at which the temperature is desired to be taken. The pipe is sealed around its upper end to prevent escape of gas, and is capped at its lower end and filled with water.

In our case the pipe is 1½" galvanized iron pipe as this size is large enough to take what is called a "pickup" thermometer which has a casing that holds some of the water and prevents the thermometer from cooling off as it is withdrawn into the air.

Our thermometer is attached to a cord and stays in the pipe at all times except when drawn out for reading. The temperature can be taken at any point desired by holding or tying the thermometer at that point.


Roof of Primary Digester
Thermometer Well of 1½" galvanized iron pipe capped on end and filled with water. Length of pipe depends on depth of digester.
Gasket or other means for securing gas-tight connection

Thermometer Well for Digesters



Gas Storage Indicator

The Editor's Comments

Is AWWA Missing a Bet on Membership?

AFTER a year of attending meetings around the country we have the feeling that several sections are missing a good bet for membership growth. We refer to the fact that in several geographical locations there are local water works associations which have memberships as large or larger than the AWWA section, and many of the members of these local sections are not members of AWWA.

Why is this? Apparently AWWA has not offered as much service to the water works men in that area as can or does the local association. For example, the Illinois section does not have a representative membership considering the number of operators in the state, while there are two other organizations, The Illinois Filter Operators Association, and a group of water works men along the shore of Lake Michigan. We are not arbitrarily picking on Illinois, but this particular problem presents a good case in point.

A number of years ago several water works operators gathered and decided that the Illinois filter operators should organize and hold meetings to discuss their mutual problems. The reason behind this decision was fundamental. Many of those men felt that the Illinois Section was "being run for the benefit of the professors and the consulting engineers and reserach men."

Whatever the actual precipitating situation, certainly the Illinois Section of AWWA was not serving the needs of the majority of the water works men in the state at that time. So the filter operators organized and with the aid and support of the State Dept. of Health have for years held meetings and short schools that have been of great benefit to the plant operator. Likewise, the operators along the shore of Lake Michigan have special problems and hold regular meetings.

We do not propose to scrap the good of either of these local organizations. There is need for that type of service, but can it not be held within the framework of AWWA. We realize that to combine these groups into a single organization immediately is next to impossible and we do not propose that AWWA accept the responsibility of the State Dept. of Health in presenting short schools for operators. On the other hand, we believe the so-called feud that is alleged to have existed in Illinois between those favoring one organization against the other and vice versa, is old enough to be dead, buried, and forgotten.

We propose that the Illinois Section arrange with the Filter Operators' Association and the Lake Shore Operators to hold a joint meeting once a year instead of separate meetings as is now done. The program of these joint meetings should be arranged to meet the varied interests. Preferably this joint meeting should be held following the operators short school.

In addition we proposed that the Illinois Section establish local divisions which will hold several one-day, or evening meetings each year within the geographical area. The programs of these meetings should be of primary interest to water works men in that area.

We believe that a combined meeting of the Section and the other organizations as outlined plus local area meetings will foster interest and good will among the operators of the state and will lead to increased membership in AWWA. We also believe that there are other AWWA sections that can do likewise. (G. E. S.)

The Clicking Canadian Section

SECRETARY Berry of AWWA's Canadian Section watched the registration sweep-hand whirl dizzily around the dial until the totalizer indicated the record-breaking paid-attendance of 555 for the Section's 1944 Conference, topping the previous record by 112.

There are reasons behind the conspicuous records of the Canadian Section in membership growth as well as meeting attendance increases. And we would say from observation that the bulk of the reasons for the noteworthy prowess of the Canadian Section, and its growing value to members, can be listed in just two words—namely, Secretary Berry.

In earlier reports of meetings of the Canadian Section we have inferred something of this sort; and, if anyone may have believed us to have somewhat overstated the case, he had only to witness the handling of the recent Canadian Conference and to see some of the "behind the scenes" activities and workings of the Section, as it was this writer's privilege to do this year. We hope that the reader of this page will already have read the first few columns of the Canadian report appearing elsewhere in this issue. The intent of these remarks is to somewhat amplify the picture of a successful meeting and a "clicking" Section, as we saw it this year and in previous years.

In the report we made reference to the luncheon of Past-chairmen with the Executive of the Section. This highly valuable annual getting together of those who have in earlier years headed the Section and the current Executive warrants especial comment.

(In Canada the term "Executive" embraces all current Section officers, the immediate past-chairman, and one representative from the Equipment Association.)

From what was seen at first hand of this particular "behind the scenes" workings of the Section it rates very high in our appraisal as a splendid procedure. It is seemingly one of the important reasons behind the successful management of the Section. In the frank and open discussion, which ensues as the result of questions as to policy and procedure for the year ahead (such questions having been developed in advance by the Secretary and the Executive) the former Chairmen and National Directors are expected to criticize current operations or management of the Section and the Annual Meeting, and more particularly to make suggested improvements in both. These suggestions are all recorded by the Secretary for consideration and action by the Executive. The discussion and questions raised in this meeting are at once extremely helpful and stimulating to the Executive in planning the future course of the Section. To these luncheons the president and the secretary of the Equipment Association are also invited. The results can be readily visualized, and represent just another bit of secretarial acumen.

As the result of observations during the Canadian Section meeting, we heard the thought expressed by one visiting member from the States that Canada's highest gift to AWWA would be a "Berry Mold" from which might be turned out other Section Secretaries.

Lacking such a "Berry Mold," we urge the several Sections of AWWA to study the policies and procedure of the Canadian Section as a pattern, from which may be taken much that is good.

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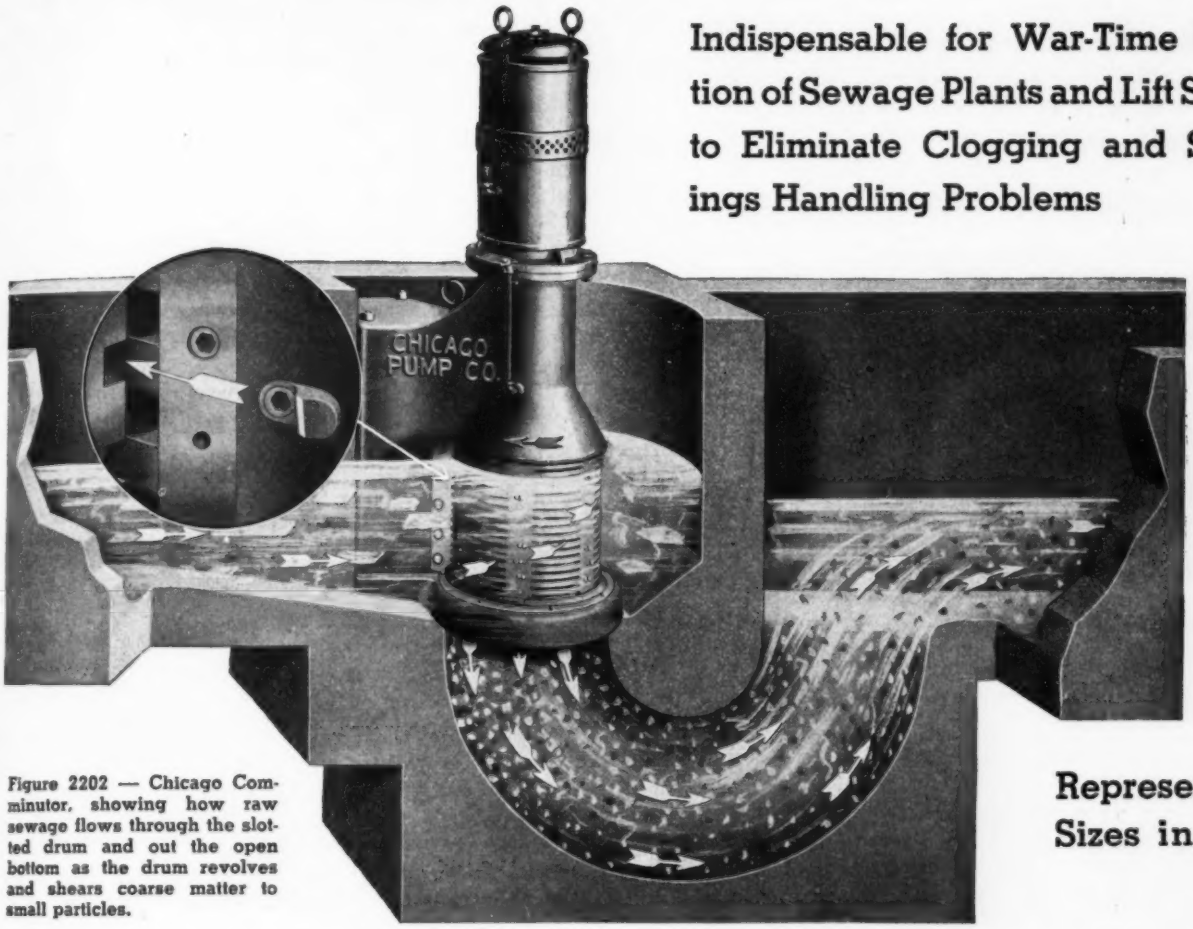

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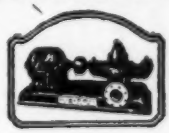

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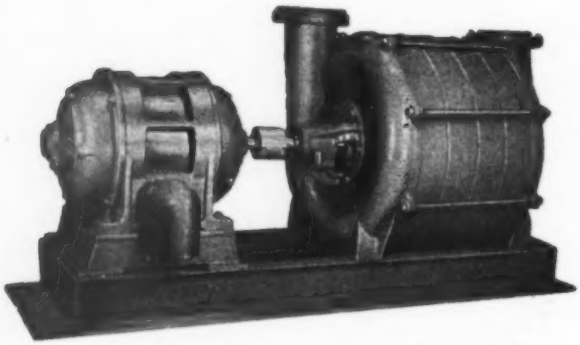

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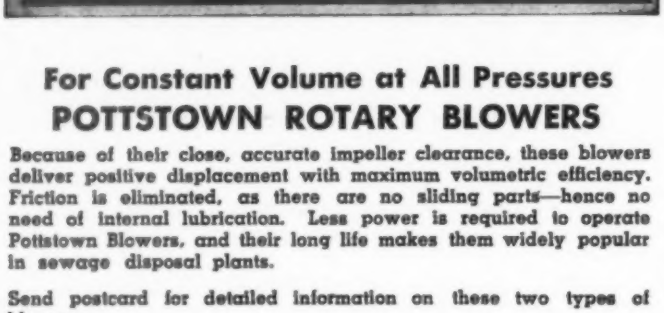

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BLOWERS AND EXHAUSTERS

MEETINGS SCHEDULED:

June 16-17—SYRACUSE, N. Y. (Hotel Syracuse).
N. Y. State Sewage Works Association. Sec'y, A. S. Bedell, N. Y. State Dept. of Health, Albany, N. Y.

June 21—KENNEBUNK, ME.
Maine Water Works Association. (Regular Meeting.) Sec'y-Treas., Earle A. Tarr, Winthrop, Me.

June 21-22—MARION, OHIO (Hotel Harding).
Ohio Conf. on Sewage Treatment. Sec'y-Treas., D. D. Heffelfinger, 1101 N. Walnut St., Alliance, Ohio.

June 22-24—OSHKOSH, WIS. (Hotel Rault).
Central States Sewage Works Ass'n. Sec'y-Treas., John C. Mackin, Supt. Sewage Treatment Works, Route 4, Madison, Wis.
(Meeting in conjunction with Wisconsin Sewage Works Operators' Conference.)

June 22-25—FRESNO, CALIF.
California Sewage Works Association. (Annual Convention.) Sec'y-Treas., J. A. Harmon, 703 Calif. State Bldg., Los Angeles 2, Calif.

July 19-21—CLEVELAND, OHIO (Hotel Cleveland).
American Society of Civil Engineers. (Annual Convention.) Sec'y, George T. Seabury, 33 West 39th Street, New York, N. Y.

Aug. 29—COLUMBIA, PA. (Columbia Water Company).
Penna. Water Works Operators' Assn. (Eastern Section). Sec'y-Treas., I. M. Glace, 22 South 22nd St., Harrisburg, Pa.

Sept. 12-13—BISMARCK, N. D. (Grand Pacific Hotel).
North Dakota Water & Sewage Works Conference. Sec'y-Treas., K. C. Lauster, State Department of Health, Bismarck, N. D.

Sept. 13-14—PITTSBURGH, PA. (Roosevelt Hotel).
Western Penna. Section A.W.W.A. Sec'y-Treas., E. P. Johnson, 418 Flannery Bldg., Pittsburgh, Pa.

Sept. 19-20—WATERTOWN, S. D. (Lincoln Hotel).
South Dakota Water & Sewage Works Conference. Sec'y-Treas., Glen J. Hopkins, State Board of Health, Pierre, S. D.

Sept. 19-22—POLAND SPRING, ME. (Poland Spring House).
New England Water Works Association. (Annual Meeting.) Sec'y, Frank J. Gifford, 613 Statler Bldg., Boston, Mass.

Sept. 24-27—ST. PAUL MINN. (Hotel St. Paul).
American Public Works Congress. (Annual Meeting). Executive Director, Frederic Bass, 1313 East 60th St., Chicago, Ill.

Oct. 3-5—NEW YORK, N. Y. (Hotel Pennsylvania).
American Public Health Association. (2nd Wartime Conference.) Chairman, Reginald M. Atwater, M.D., 1790 Broadway, New York, N. Y.

Oct. 12-14—PITTSBURGH, PA. (Hotel William Penn).
Federation of Sewage Works Associations, Exec. Sec'y, W. H. Wisely, Illinois Building, Champaign, Ill.

Oct. 12-14—PITTSBURGH, PA. (Hotel William Penn).
Penna. Sewage Works Association. Sec'y-Treas., Bernard S. Bush, Kirby Health Center, Wilkes-Barre, Pa. (Joint Meeting with Fed. Sew. Wks. Assns.)

Oct. 17-19—AUSTIN, TEXAS (Hotels Austin & Driskill).
Southwest Section A.W.W.A. Sec'y-Treas., George J. Rohan, P. O. Dr. 449, Waco, Texas.

Oct. 23-24—KANSAS CITY, MO. (President Hotel).
Missouri Valley Section A.W.W.A. Sec'y-Treas., E. L. Waterman, 104 Engineering Hall, University of Iowa, Iowa City, Ia.

Oct. 30-31—PITTSBURGH, PA. (Hotel William Penn).
Engineers' Society of Western Pennsylvania. Chairman, H. M. Olson, Hotel William Penn, Pittsburgh, Pa.

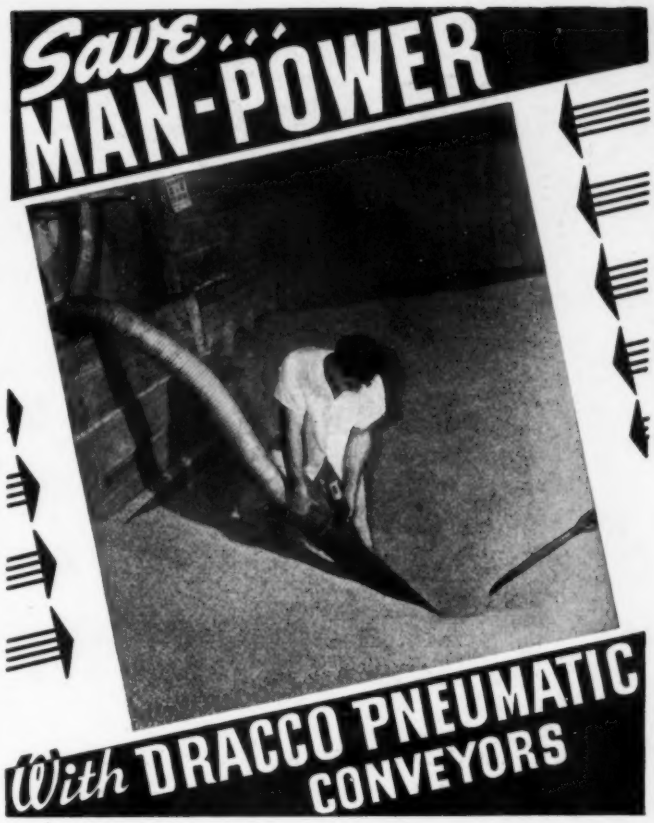
Nov. 2-4—ATLANTIC CITY, N. J.
New Jersey Section A.W.W.A. Sec'y, C. B. Tygert, Dist. Mgr., Wallace & Tiernan, Inc., Box 178, Newark, N. J.

Nov. 8-10 — PHILADELPHIA, PA. (Benjamin Franklin Hotel).
Four States Section A.W.W.A. Sec'y-Treas., H. Lloyd Nelson, U. S. Pipe & Foundry Co., Broad and Chestnut Sts., Philadelphia, Pa.

and

Penna. Water Works Operators' Assn. Sec'y-Treas., I. M. Glace, 22 South 22nd St., Philadelphia, Pa. (Second Joint Wartime Conference.)

Nov. 16-18—PETERSBURG, FLA. (Swannee Hotel).
Florida Section A.W.W.A. Sec'y-Treas., Prof. A. P. Black, University of Florida, Gainesville, Fla.



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MUNICIPAL WATER SOFTENING PLANT.....Sandusky, Ohio
MUNICIPAL WATER SOFTENING PLANT.....Ames, Iowa
LEMIEUX ISLAND FILTRATION PLANT.....Ottawa, Ontario
MAHONING VALLEY SANITARY DISTRICT.....Niles, Ohio
MUNICIPAL WATER PLANT.....Columbus, Ohio
MUNICIPAL WATER PLANT.....Peru, Ill.
U. S. GOVERNMENT FILTRATION PLANT..Ft. Leavenworth, Kans.
MUNICIPAL WATER PLANT.....Hamilton, Ohio
BACHMAN WATER PURIFICATION PLANT.....Dallas, Texas
MUNICIPAL WATER PLANT.....Richmond, Va.
MUNICIPAL WATER PLANT.....Springfield, Ill.
MINNEAPOLIS-SAINT PAUL SANITARY DISTRICT..St. Paul, Minn.
(Sewage Disposal Plant, 2 installations)
MUNICIPAL WATER PLANT (2 installations).....Milwaukee, Wis.
MUNICIPAL SEWAGE DISPOSAL PLANT...Oklahoma City, Okla.
MUNICIPAL SEWAGE DISPOSAL PLANT.....Denver, Colorado
MUNICIPAL WATER PLANT.....Covington, Ky.
MUNICIPAL WATER PLANT.....Ann Arbor, Mich.
CLAYTON SEWAGE DISPOSAL PLANT.....Atlanta, Ga.
SEWAGE DISPOSAL PLANT (2 installations).....Cleveland, Ohio
MUNICIPAL WATER PLANT.....Benton Harbor, Mich.
MUNICIPAL WATER PLANT.....Warren, Ohio
MUNICIPAL SEWAGE DISPOSAL PLANT.....Detroit, Mich.
MUNICIPAL WATER PLANT.....Flint, Mich.
CITY OF TORONTO WATER WORKS PLANT.....Toronto, Ontario
WATER FILTRATION PLANT.....Ottawa, Kansas
EL RENO WATER TREATMENT PLANT.....El Reno, Oklahoma
CITY OF GRAND FORKS.....Grand Forks, North Dakota
MUNICIPAL SEWAGE PLANT.....Pittsburgh, Pennsylvania
WATER FILTRATION PLANT.....Wichita, Kansas
INDIANAPOLIS WATER CO.....Indianapolis, Ind.
WATER FILTRATION PLANT.....Appleton, Wis.
MUNICIPAL WATER PLANT.....Chillicothe, Ohio

And a large number of installations in water works of Ordnance Plants.

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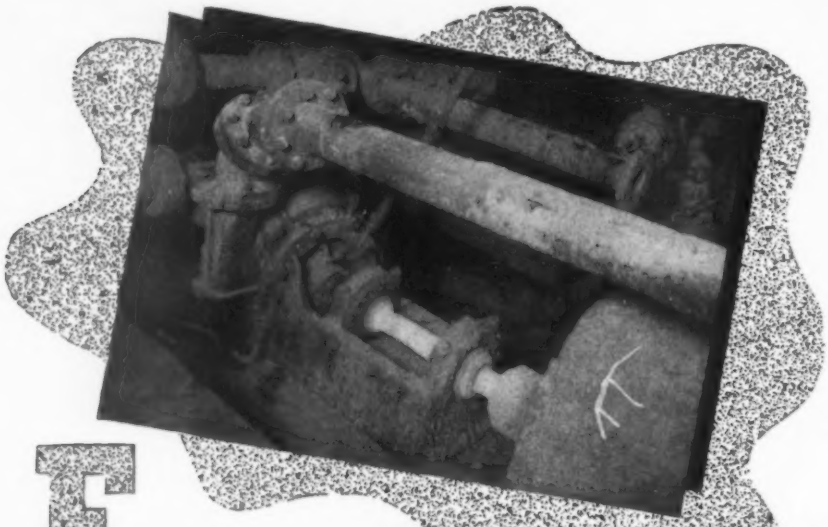
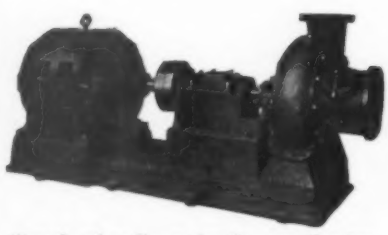


"FULL OF GRIT"

Engineers who have wondered about the origin of this expression may get some idea from the above illustration. This Morris Centrifugal Pump is certainly "full of grit"—literally as well as figuratively. The stamina which has enabled it to operate with complete satisfaction on this difficult slurry-handling service is typical of the quality built into all Morris Pumps: whether used for clear water, chemicals, pulpy or abrasive mixtures. Have you the Morris bulletins on pumps for your requirements? If not, be sure to write for copies.



Non-clogging Pump for Sewage Service

Double Suction Horizontally Split Pump for Water

MORRIS MACHINE WORKS
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CENTRIFUGAL PUMPS

Here and There with Doc Symons

MAY WE quote from a letter we received some time ago—"By the way there is an organization in the state capitol, that is supposed to give advice to municipalities in regard to the cost of various municipal functions. Recently, they sent a printed bulletin to the city fathers. It said that 'sewage treatment costs above those stated should be looked into. . . .' For primary treatment of sewage the cost was given as 'from a few cents to 30 cents per capita per year.' Imagine that—Why in many plants, operators of certain grades are r e q u i r e d and thirty cents wouldn't pay for the common labor let alone 24 hour attendance. Here I am with an $18,000 budget and a 25,000 population and don't do any filtering of sludge although equipped to do so.—Now I ask you is 30 cents enough for primary treatment? If you are interested perhaps you can do a Westbrook Pegler for the Sanitary Field on this subject. . . ." Thanks for the compliment, but it seems to me that our correspondent has done pretty well himself.

* * *

While reading our favorite weekly comic magazine, *The Patent Digest*, we ran across a patent issued for a "Nut Gathering Device." Holy little red roarin' tomato cans! Don't tell us they have patented the Washington Alphabet Bureaus.

* * *

It is well known throughout the State of Michigan that N. G. (Ance) Damoose never misses an opportunity to proclaim the wonders of "Battle Creek Plant Food" (digested sludge to you). According to Ance it is well supplied with Vitamin B_1 as well as other desirable constituents. In recognition of Mr. Damoose's extolling of the virtues of his product (he is, so he says, no salesman), the Michigan State Sew. Works Conf. in conjunction with some of the faculty of Michigan State College presented him with the

degree of B.S. in B_1 at the recent meeting in Lansing. In the presentation, Mr. Paul "Bunyan" Stegeman commented on other accomplishments of the recipient — something about ability to throw something or other a great distance—and make it stick.

* * *

Can you imagine any better assignment for a field engineer than to make a study of sanitary conditions preparatory to the construction of a sewage project in Honolulu, T. H.? We certainly envy Harry Kinsel, who joins C. Frank Johnson, formerly Chief Engr. of the Louisville Sewerage Commission, in being sent to Hawaii for Metcalf and Eddy who are to prepare a report on the sanitary engineering problems, facilities and remedies for Honolulu. M-m-m-m Smell those beautiful flowers, feel that lovely blue surf and see that moonlight over Pelee. Who says a sanitary engineer's life is not a bed of roses???

* * *

H. S. Morse, Gen. Mgr. of the Indianapolis Water Co., says, "A committee is a group that keeps minutes but spends hours."

* * *

Some time ago we expressed the desire to know whether this column was being accepted by our subscribers. Since then we have received a gratifying number of favorable comments. We haven't, however, received many contributions to the column and would therefore like to repeat our request for stories from our readers.

* * *

If the miles traveled by E. L. Filby in the last several months for **Blueprint Now!** mean anything then the efforts have been successful. By the time this issue is off the presses "E. L." will have covered over 50,000 miles and more than 80 meetings. Traveling these days is no cinch either, but when there is need for a good job to be done you can always find a good man to do it in spite of difficulties. (Incidentally, did you know that "E. L." himself originated the slogan "**Blueprint Now?**")

* * *

We saw recently where the OWI had rewritten the history of the United States. We must "get hold" of a copy to see if it says that PWA and WPA invented water purification and sewage treatment.

* * *

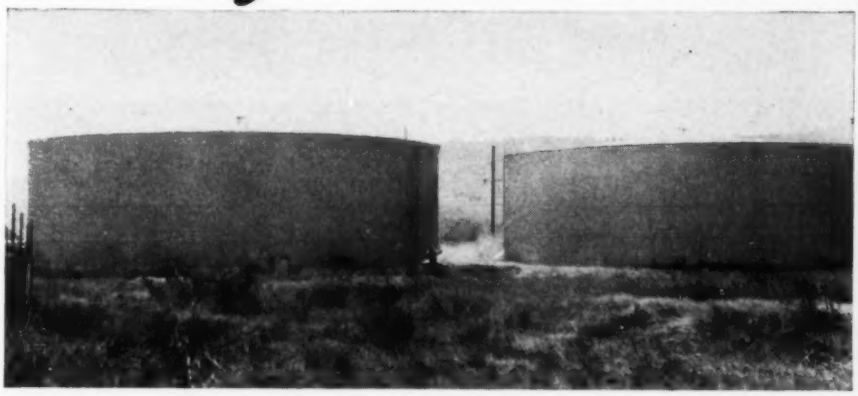
W.W.&S. isn't the only one!—Every now and then some **subscriber** writes that he has just received a card telling of the advantages of reading *Water Works and Sewerage* and inviting him to subscribe thereto. He thinks we are a bunch of dopes not to know that he is already a subscriber. We were therefore relieved to learn that *Harper's Magazine*, no less, has the same trouble. Only difference between us and *Harper's* is that it was Groucho Marx who wrote them, saying among other things, ". . . thanks for your kind and bewildering offer. It was sweet to hear from you and to learn how a successful magazine operates. . . ."—When you receive a subscriber's offer from us will you be as coy as "Groucho"?

At the Illinois Section meeting it was old home week for several alumni of the Ill. State Water Survey. Uncle Louie von Birdwhistle (Lou Birdsall to you), C. C. "The Swede" Larson, T. E. (no relation) Larson, Max Suter, Herb White, W. D. Gerber, Yours Truly, and Clair S. (for nothing) Boruff of Hiram Walker's (We'd like to write the story of how they solved a waste disposal problem — disposal of their product is, of course, no problem).

* * *

Here is a suggestion for the AWWA meeting next year (1945). How about having Throckmorton P.

Reilly PAINTS



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BUY BONDS

Gildersleeve, Water Commissioner of Summerfield, attend the meeting as a special guest star to do a radio script as the entertainment on the evening of the president's reception. If Gildersleeve can not bring Liela, Miss Goodwin, Peavey, LEE-Roy, and the rest of the cast, why can't he do a script that will utilize some of the Thespian talent that abounds in AWWA.

* * *

Boy! Some of these new-fangled equipment people are getting rather fancy. Sid Wilson of Rusta-Restor told us in an offhand way recently that they are using platinum electrodes in their cathodic protection. Imagine that—platinum, no less.

* * *

You are no doubt acquainted with the physiological effect of change in water supply on the normal functioning of the intestinal tract. One of our correspondents recently wrote of suffering those effects in a city taking water from the Ohio River. "Having the Ohio River Collywobbles" was the way he put it.

* * *

Sam Ellsworth was recently elected Pres. of the Boston Soc. of Civ. Engrs., the oldest Engr. Soc. in this country. Congrats! We like to see the young fellows get ahead. Speaking of Sam reminds us of the time he told about some one referring to him as a man who believed in Imhoff Tanks. "Just like being called a Unitarian," said Sam.

* * *

Next time you see Sam Morris, AWWA Pres., ask him to tell his story about the WAVE who didn't like the WAC's paper.

* * *

So Sorry Dept.—Space limitation in this issue precludes the use of some swell stories from the Ohio AWWA Sect. meeting at Columbus, but look for them later.—Incidentally, the Information Please program at that meeting was one of the best of the year. It was sparked by Wendell (Clifton Fadiman) La Due of Akron, and to our way of thinking Ohio has reasons enough for picking Wendell R. as their candidate for the AWWA presidency.

* * *

Famous Last Lines: Wonder what ever happened to the report on the study of the Guggenheim Process in New York?

* * *

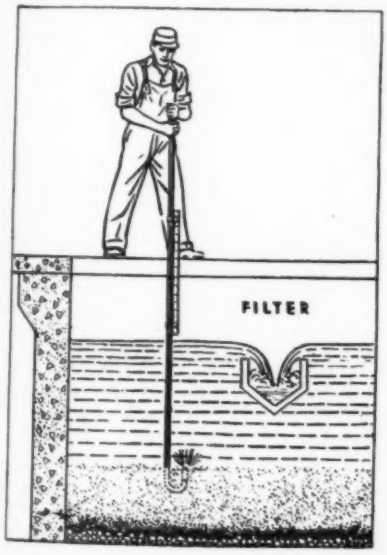
Famous last line No. 2.—Save your *1943* June issue so you will be sure to have a complete W.W.&S. Reference and Data file, because none of the 1943 R. & D. material was repeated this year.

MANUFACTURERS' and EQUIPMENT News

New Instrument Measures Sand Expansion with a Light

Designed to assist in maintaining filter beds in proper conditions obtain maximum filter runs and reduce the use of wash water to a minimum, a new instrument has been developed by Builders-Providence, Inc. (division of Builders Iron Foundry), Providence, R. I. This instrument, called a Hook Light Sand Expansion Gauge, consists of a tube of corrosion-resisting metal sufficiently long to allow the operator to reach the filter bed from the walkway. A handle at the upper end of the tube encloses dry cell batteries and a switch. The lower end of the tube is bent into a hook with small light bulb and magnifying lens at the end. On the side of the tube is an adjustable scale which can be clamped at any height.

To use the Hook Light, the operator lowers the tube until the bottom of the bend just touches the top of



the unexpanded sand bed. With the unit in this position, he adjusts the scale so that its lowest graduation is in line with a reference mark. During back washing he raises the instrument until the light may just be observed. Since the scale has been

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Good Tasting
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Hydrodarco, the *quality* activated carbon specially made for water treatment, does a real job of removing odors and unwanted tastes. Standardize on Hydrodarco for performance you can depend on—and maximum palatability control per dollar.

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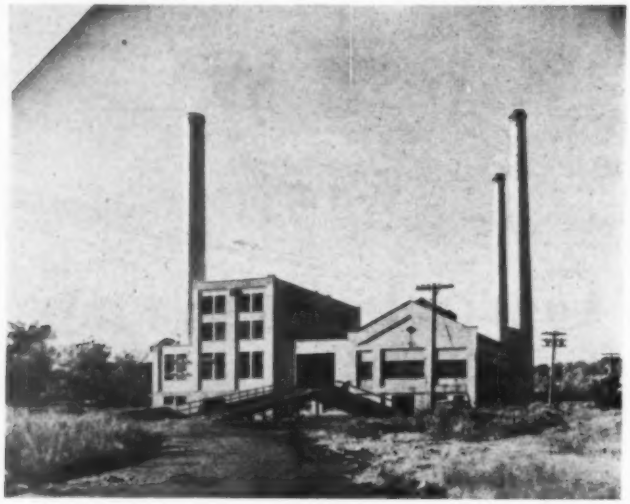

Incineration plant at New Rochelle, N. Y., where population increases necessitated two additions to the plant's original capacity. Morse Boulger engineers handled the original plant and the additions.

Why an "ENGINEERED" Incineration Plant?

Because some six branches of engineering enter into the design and construction of an efficient and economical incineration plant. The skilled incineration specialist calls upon his knowledge of chemical, mechanical, electrical, sanitary, civil and traffic engineering because all enter into the problem. Each community's problem is different. "Packaged" incinerators are not for the community wanting the best. Design as well as construction is important.

Morse Boulger engineers can call upon more than fifty years of incineration service to cities and towns. They have built up a reputation of installing well-engineered plants. Assistance in laying out plans is available to those who request it.

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Representatives in Principal Cities

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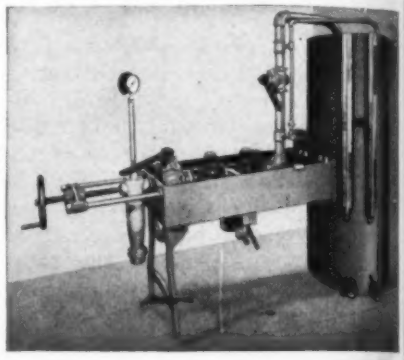
compensated for the distance from the light to the bottom of the bend, the amount of expansion (in inches) is then read directly on the scale. Operators report that they find the new instrument far more accurate than the makeshift cup or bottle method and easier to operate. Duplicate readings within 1/16 inch may be consistently obtained. Bulletin 348 describing the new Hook Light may be obtained by writing Builders-Providence, Providence, R. I.

New Meter Prover

A newly designed meter prover has been announced by the National Meter Division of Pittsburgh Equitable Meter Co. The National Prover has been constructed to confirm with the ideas and needs of practical



meter maintenance men and accuracy, accessibility, ease, and speed in testing meters have all been incorporated in the design.

This Prover will test, by the volumetric method, meters up to and including the 2-inch size. Flow rates are determined by an inbuilt rate of flow indicator which is calibrated to accurately record flows of from 1/16 gpm. to 160 gpm.

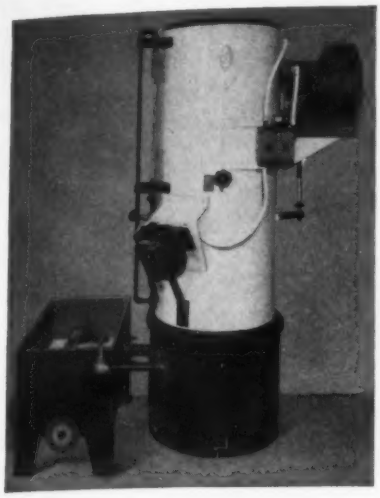
The two compartment, cylindrical tank, carries dual percentage of error scales that are adjustable for calibration. These scales are graduated to read directly in percentage of error at four points. Nordstrom lubricated plug valves are provided to control the flow.

Additional information on this National Meter Prover may be obtained by writing Pittsburgh Equitable Meter Co., Pittsburgh 6, Pa.

Sludge Collector for Small Round Settling Tanks

A new sludge collector for the smaller-diameter settling tanks, known as the Link-Belt Type "B" Circuline Collector, has been announced by Link-Belt Co.

Where average domestic sewage is



UNIVERSAL FEEDER

Three sizes cover a feeding range of 1 to 10,000 lbs. per hour. The high speed agitator in the dissolving chamber and Rotameter for measuring the water supply are used especially for dissolving Ferrisul, Ferrifloc and low grade Alum. The makeup tank illustrated introduces the dissolved chemical into a centrifugal pump or eductor without admitting air.

OMEGA

Improved plant and manufacturing facilities permit early deliveries of

"THE LAST WORD IN CHEMICAL FEEDERS"

Universal Dry Feeders
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are kept in stock or can be assembled from stock parts within a few days.

Priority of AA-3 or better is required.

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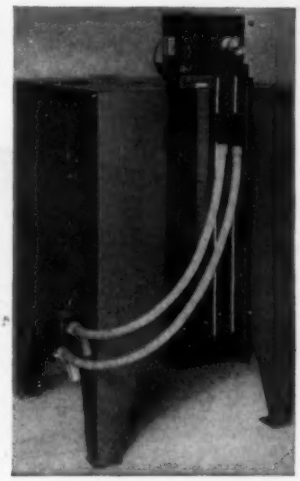
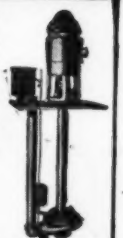


PRECISION FEEDER

Feeds hypochlorite, Calgon Ammonia, Ferric Chloride and acid solutions by gravity. Feeders are pre-set by a dial to the desired rate of feed. Accuracy is 99% plus. Wood, steel, lead lined or asphalt lined tanks are furnished. Where electricity is not available, operation is accomplished by an eight-day spring motor.

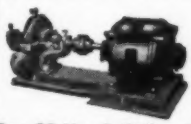
Plan Ahead With WAR-TESTED PUMPS "by Aurora"

The splendid record of thousands of Aurora Pumps on a myriad of war services is your assurance that your post-war needs will be taken care of superbly as you, too, install Pumps "by Aurora"—the Products of Experience—made by exclusive builders of fine pumps.



NSA Aurora Centrifugal Sump Pump

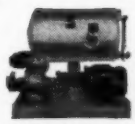
Aurora Deep Well Turbines for all conditions—4" to 24"



Type AD Hor. Split Case, Two Stage Centrifugal

Type OD Hor. Split Case Double Suction Single Stage Centrifugal

APCO TURBINE-TYPE PUMPS—the simplest of all pumps. Ideal for small capacity, high head duties. Silent, compact and lasting.



APCO Horizontal Condensation Return Unit

Type GMC Close-Coupled Centrifugal

Write for **CONDENSED CATALOG OR**

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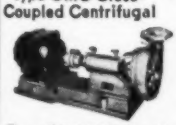

Type GGU Side Suction Single Stage Centrifugal

APCO Single Stage Turbine-Type

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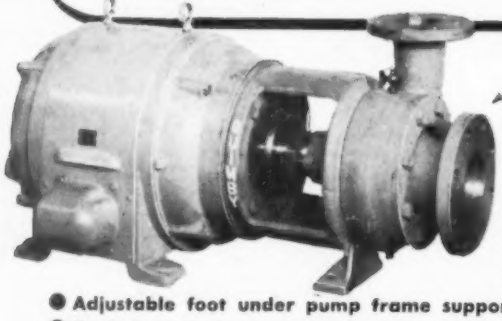
QUIMBY PUMPS

the new Quimby close-coupled centrifugal Pump



- Compact, rugged, efficient, low cost.
- Hydraulically and mechanically balanced.
- Double volute construction on larger sizes to eliminate shaft deflection.
- Adjustable foot under pump frame supports pipe loads.
- Sealed shaft sleeve protects entire shaft extension.
- Sizes 1 in. to 6 in. for capacities to 1000 GPM, heads to 450 ft., temperatures to 300°F.

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A Filter Medium For All Purposes

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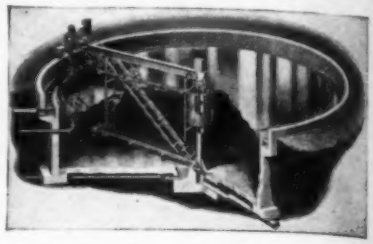
SULPHATE of IRON
FOR WATER AND SEWAGE TREATMENT
E. M. SERGEANT PULP AND CHEMICAL CO., INC.
EMPIRE STATE BUILDING
NEW YORK 1

treated, the new Type "B" collector is recommended for tanks of up to 55-ft. diameter.

In Circuline collectors, the settled sludge is collected and continuously moved radially, inwardly, on tank floor by a slow-moving scraper flight type conveyor and sludge plow, into a sludge hopper from which the sludge is withdrawn.

The conveyor is mounted on a power-rotated, centrally pivoted



bridge spanning half the diameter of tank. The drive, located at outer end of bridge span, consists of a motorized speed reducer carrying a sprocket wheel which engages a heavy galvanized two chain located and anchored in the effluent trough. The outer end of bridge is pulled by this chain, or it might be said to "walk around" the chain.

When used in primary settling tanks, a screw conveyor is supported along the one side of bridge span, for the purpose of confining and more effectively moving the scum and grease to a scum trap. This feature prevents wind pressure from blowing the collected scum out of reach.

For further information write for Book No. 1982. Address request to Link-Belt Co., Philadelphia 40, Pa., or to the Chicago or San Francisco office.

Simple Means for Boiler Feed Water Testing

There is now available a portable A-B-C type apparatus quite suitable for the purpose of determining or testing boiler feed water. This apparatus is the Taylor Boiler Water Comparator, a compact set for determining pH in a range of 7.2 to 11.6, and phosphates in the range of 5 to 100 ppm. Complete apparatus is contained in a durable case only 12" x 6" x 10", and procedures are simplified so that the chemist can readily explain the operation to a non-technical operator.

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for a fighting Navy!

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Earle Gears are used to help the Navy keep its ships and shore equipment functioning efficiently. The use of Earle Gears ranges from those in the operating machinery for elevators in "flat-tops" to sprinkler system valve operating gears in landing craft and includes gears for all kinds of equipment such as capstans, steering engines, Anti-Aircraft guns, boat cranes, etc. For more than 40 years Earle has been making gears of most every type and size to meet both usual and unusual requirements. For details regarding Earle Gears, write for Bulletin 42-G.

THE EARLE GEAR & MACHINE CO.
4725 STENTON AVENUE, PHILADELPHIA 44, PA.

EARLE GEARS

SALES OFFICES:
149 Broadway, New York 6, N. Y.
901 Davis Avenue, Pittsburgh 12, Pa.

A life-giving drink of fresh sea water

PERMUTIT DESALTING BAG
INSTRUCTIONS
1-FILL BAG TO LINE WITH SEA WATER
2-ADD BRIQUET OF CHEMICAL. ROLL TOP OF BAG DOWN AND SNAP SECURELY.
3-ALLOW BRIQUET TO STAND FOR A FEW MINUTES. THEN KNEAD BAG WITH HAND FOR 10 MINUTES UNTIL BRIQUET IS BROKEN INTO A FINE POWDER.
4-SHAKE BAG OCCASIONALLY FOR 30 MINUTES SO DESALTING MATERIAL IS KEPT IN CONTACT WITH WATER.
5-NOW SUCK CLEAR FILTERED DRINKING WATER THROUGH OUTLET TUBE.
THE PERMUTIT COMPANY
WORLD'S LEADING WATER CONDITIONING SPECIALISTS FOR MORE THAN 30 YEARS
PATENT PENDING

THIS flyer, down at sea, may suffer many hardships. But he'll be spared the most dreaded of all—thirst. He'll drink sea water—and live!

Stowed in his rubber raft, he'll find a *Permutit Sea-water Desalting Kit. It consists of a plastic bag and a supply of salt-removing briquets. That's all he'll need to change salt sea water into fresh, clear drinking water in a few minutes. The kit occupies only one-tenth the space of the drinking water it produces.

The Desalting Kit was developed by chemists and engineers at Permutit, and accepted by the U. S. Navy, Army and Air Transport Command.

Permutit is helping thousands of war plants and Army and Navy establishments to do a better war job. We are proud indeed that our skill enables us also to make the tough job of our front-line fighting men a little easier, a little safer.

The Permutit Co., Dept. G1, 330 West 42nd St., New York 18, N. Y. In Canada: Permutit Co. of Canada, Ltd., Montreal.

*Trademark Reg. U. S. Pat. Off.

PERMUTIT

Serving industry and the armed forces . . . with Good Water

HILL-HUBBELL

TO identify our quality workmanship to you, our 80 lb. Kraft paper wrapper is imprinted with our name—"HILL-HUBBELL & Co.

Buy pipe protection wisely.
Buy GOOD pipe protection.
Buy HILL-HUBBELL pipe protection.

GENERAL PAINT CORPORATION
HILL, HUBBELL & CO. • Division • Cleveland, Ohio
• EXPORT OFFICE: SAN FRANCISCO, CALIFORNIA, U. S. A. •

IMPROVED JOINTING COMPOUND
Tegul-
MINERALEAD
for Bell & Spigot Main

- Sulphur base; quick sealing, speeding laying and backfilling.
- 10 lb. ingot form, easily handled, stored and shipped. Impervious to rain. Cannot change composition.
- Makes permanently tight joints. Goes 3 to 5 times as far as lead, helping conserve a strategic war metal.
- For money-saving information, write

The ATLAS MINERAL Products Company of Pa.
Mertztown Pennsylvania

EDSON
DIAPHRAGM PUMPS
Hand Sizes 2", 2½", 3", 4"
Power Sizes 3" and 4"
Open Discharge or Force Pump
Edson Special Suction Hose
Red Seal Diaphragms
Strainers and Foot Valves
Hose Spanners—Adapters

THE EDSON CORPORATION
Main Office and Works: 49 D St.
South Boston, Mass.
New York: 142 Ashland Pl., Brooklyn

The Taylor Boiler Water Comparator is designed to determine ortho-phosphate only, but pyro- and meta-phosphates can be converted to the ortho-phosphate by boiling an acidified sample. A determination can then be made with the comparator.

Only three indicators are used to determine pH and three color slides are furnished with the comparator.

For further information on this compact little unit, write the Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa., or Eimer and Amend, 635 Greenwich St., New York, N. Y.

Chlorine Dioxide, New Bleach

Chlorine dioxide, a bleach known to be two and one half times as powerful as chlorine, is now available for industrial purposes by means of a process developed by The Mathieson Alkali Works and described by E. R. Woodward at the meeting of the American Institute of Chemical Engineers at Cleveland.

Although chlorine dioxide has been known to chemistry for a long time, its use has been impractical because it does not keep, and therefore cannot be manufactured in bulk for shipment. The new process overcomes this difficulty by providing a safe, practical method by which the user prepares the bleach from chlorine and sodium chlorite at the point, and in the quantity, required.

Chlorine dioxide has already proved to have specific values in improving taste in public water supplies, checking blue mold in citrus fruits, and reducing spoilage in canned foods. On an experimental scale, sterilizing the atmosphere with chlorine dioxide increases the yield of penicillin.

New Line of Rotameters

Several important features claimed to be exclusive are listed by Cochrane Corporation, of Philadelphia, in announcing Series R-100 Rotameters. These meters are of the indicating area meter type, covering sizes from ⅛ in. to 3 in., with both free and guided floats. Floats may be viscosity or density compensated. Metering tubes are of extra heavy wall Pyrex borosilicate glass formed on mandrels, annealed, polariscope inspected and check-gaged by precision ball test. Features include:

Spring stop floats, high pressure stuffing boxes, single external adjustment of stuffing boxes by wrench,

white-backed metering tube, interchangeable calibration scales, and constant tension guide rod.

The Cochrane-Rotameter (Inc.) line of Rotameters covers: Stet Free Float and Liquid Float Types (260 mm. 10 in. Scale Length), Extra Length Guided Float Type (625 mm. 25 in. Scale Length), Dashpot Type

for Pulsating Flows, Panel Mounting Type, Portable Type, Rotameters for Opaque Fluids, Rotameters for Vapors Containing Condensibles, Rotameters with Remote Indicators, Recorders, Integrators, Automatic Controllers and Automatic Proportioners. A catalog, Publication R-100 is available.

"Handi-Lift" P & H Chain Hoist

The small "Handi-Lift" chain hoist developed by Harnischfeger Corporation introduces many new features into the low price electric chain hoist field. These include increased utility by quick interchangeability to bolt, hook, or trolley mounting, with changeover requiring the loosening of one bolt only. Also, in trolley service, it can be suspended either parallel or crosswise to beam for greater flexibility. Fully enclosed construction permits use under any condition of weather, dust, moisture, or acid fumes. While the unit is rated at 500 pounds, a genuine hoist motor supplies unusually high reserve capacity. The chain is proof-tested for 1800 pounds. Operation is by handy pull cord actuating a simple lever toggle arrangement, which leaves one hand

Cut Coagulant Costs with

TENNESSEE CORPORATION Ferri-Floc

Cold water soluble ferric iron. A coagulant for all types of water treatment and sewage. Also adaptable for waste water treatment.

Write us today for actual case histories of plants now using the ideal Ferric Coagulant.

The Mark of Quality

TC TENNESSEE CORPORATION

Tennessee Corporation

ATLANTA, GEORGIA LOCKLAND, OHIO

Combined

SEWER & PIPE FINDER

and

AMPLIFYING RECEIVING COIL

THE U. S. GOVERNMENT BUYS THEM

Send for Circular

Frank N. Blake, North Adams, Mass.

BAILEY METERS AND CONTROLLERS

FOR SEWAGE TREATMENT AND WATER SUPPLY . . .

● Venturi Tubes, Weirs, Flumes, Nozzles and other primary elements; Mechanically and Electrically operated Registers and Complete Automatic Control Systems.

BAILEY METER COMPANY

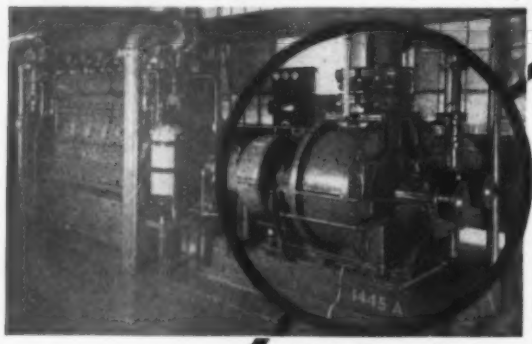
1672 IVANHOE ROAD • CLEVELAND, O.

Bailey Meter Co. Ltd., Montreal, Canada

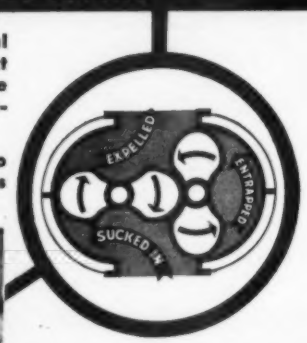
When the Time Comes --

—you will want to specify the most economical blowers for your complete sewage treatment plant. The proved economy of Roots-Connersville Blowers is found in the many years of trouble-free service rendered.

Write for Bulletin today—and be prepared to go ahead with planned improvements as soon as war-time restrictions permit.



"R-C" Blower, driven by engine using "sludge" gas, installed at Sioux Falls, S. D., Sewage Treatment Plant.



POSITIVE DISPLACEMENT

Twin impellers alternately suck in, momentarily entrap, and then expel definitely known amounts of air, resulting in positive delivery of four equal volumes each revolution of drive shaft. Impellers need no seal or lubrication. Capacity varies with speed. Pressure automatically builds up to overcome resistance on discharge side.

ROOTS-CONNERSVILLE BLOWER CORP.
406 Mount Avenue Connersville, Ind.

Roots CONNERSVILLE SINCE 1854 Aerating BLOWERS

[SC]² PRECISION CONCRETE CONTROL **For**

Dams, Tunnels, Sewers

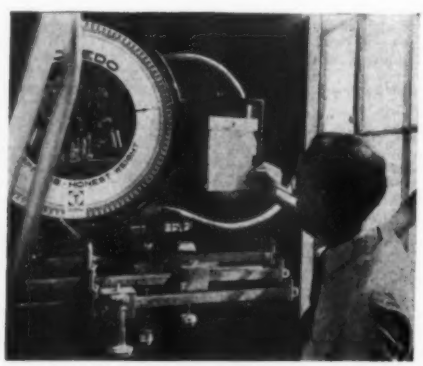
Provides fast, accurate batching to these tolerances **Weight of DRY Aggregates ¼%. Water, ½ gallon per cubic yard.**

[SC]² CONTROL Includes:

Moisture Determination. Test made in one minute. A test for every batch when necessary.

Moisture Compensation, for moisture content of aggregates. Compensation is instantaneous and automatic. No calculations, tables or charts necessary.

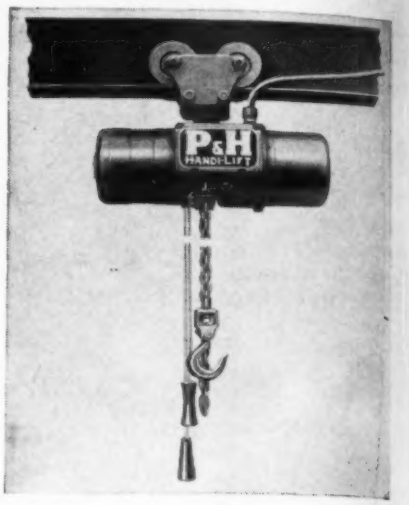
Graphic Record, showing the delivered weight of each ingredient in every batch. Reveals all weighing errors. Valuable aid to inspectors. Reduces inspection cost.



Let us show you what [SC]² CONTROL has done for small and large projects and ready-mix plants. Write today for full information.

SCIENTIFIC CONCRETE SERVICE CORPORATION
McLachlen Building, Washington, D. C.

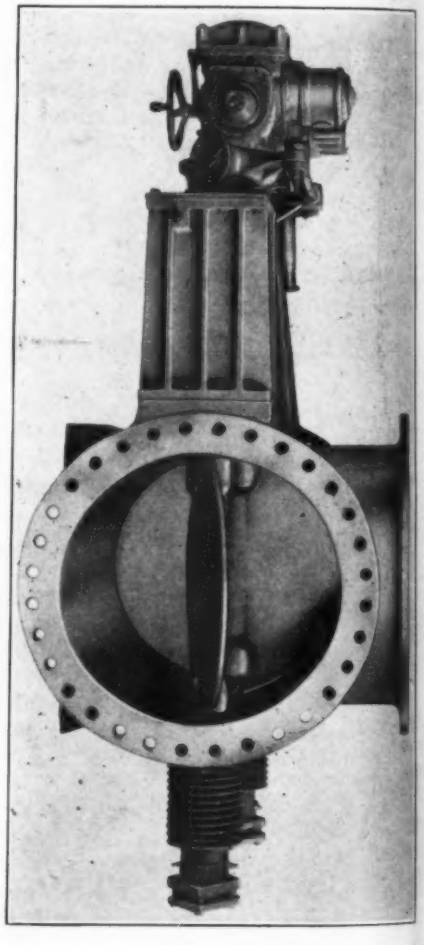
free to guide the load. The "Handi-Lift" motor is of high-starting torque. The unit operates on 3 phase 60 cycle, 220 or 440 volts. "Handi-



Lift" bulletin No. H-23, giving specifications, is available on request from the Hoist Division, Harnischfeger Corp., Milwaukee 14, Wis.

Three-Way Valve

R-S Products Corp. has adopted the simplified design and quick action of the butterfly valve to a three-way valve, known as type No. 604. This valve is designed for quick in-



terchange and flow blending or mixing service for all pressures from 15 to 900 psi., and may be adapted to manual control, as well as power operation and elevated temperatures. For further information, write R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

Dr. Davidson Pres. Carbide and Carbon

Dr. Joseph G. Davidson has been elected President of Carbide and Carbon Chemicals Corporation and Carbide and Carbon Chemicals, Ltd., units of Union Carbide and Carbon Corporation. Dr. Davidson holds degrees in chemistry from the Univer-

Dr. J. G. Davidson

sity of Southern California and Columbia University. He participated in the early work in synthetic organic chemistry which led to the foundation of Carbide and Carbon Chemicals Corporation. He has served in this company in technical and executive capacities since its formation, having been Vice President in charge of sales during the last 12 years.

Yeomans Announces New Representative in Denver

Representation for Yeomans pumping and sewage treatment equipment in the Rocky Mountain area was completed recently by the association of Thompson Pipe and Steel Co. of Denver with the Yeomans engineering and sales organization. The Denver company will represent Yeomans in the sale of all products in Colorado and in the sale of sewage pumps and sewage treatment equipment in the states of Wyoming and New Mexico.

Thompson Pipe and Steel Co. dates its formation back to 1878 when it began the fabrication of steel pipe which gave it its name. Today sales efforts are centered about equipment for water control, sewage treatment, highway construction and industrial use.

Both plants of Thompson Pipe and

CEMENT GUN COMPANY
"GUNITE" CONTRACTORS
GENERAL OFFICES—ALLENTOWN, PENNA., U.S.A.

A DAM REINTEGRATED WITH "GUNITE"

The first photo shows dsintegrated buttresses of a dam at the Hydro Electric Plant of the Central New York Power Corporation, Trenton Falls, New York.

In the middle is shown how we restored the buttresses with lean "GUNITE" to almost their original lines with reinforcing mesh placed preparatory to applying a final two inch "GUNITE" surfacing. The final view is of the job after completion.

This "GUNITE" was carried down to the rock stream bed on both the up-stream and down-stream sides.

After ten years this work still looks as good as new.

Our Bulletin No. 2200 describes similar jobs we have done as well as hundreds of other uses of "GUNITE." Write for copy.

MANUFACTURERS OF THE "CEMENT GUN"

☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆

Permanent . . . . .

REDWOOD PIPE Saves critical materials! Long known as a pipe with greater carrying capacity than metal or concrete. Does not clog, scale or pit.

LOWER labor, installation and maintenance costs. Long life, no electrolysis, contamination of water, or destruction by sulphur, salt water or other mineral impurities. New type Wyckoff California Redwood Pipe for water supply and sewage lines is a proven product.

A. Wyckoff & Son Company

ELMIRA, N. Y.

Originators of Machine Made Wood Pipe

1855—Our 89th Anniversary—1944

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DIGESTER GAS STORAGE HOLDERS

WET OR DRY SEAL TYPES

Storage of digester gas during peak periods of production can greatly extend the economies of its use by affording a reserve supply for continuous use. We are one of the foremost designers and producers of both wet and dry seal gas holders in capacities from 100 to 21,000,000 cu. ft. In many instances the storage of gas in a *dry* state offers distinct advantages. It will pay you to investigate *both* types, and get the facts on the record of Stacey Brothers equipment. Write today.

The STACEY BROS. Gas Construction Co.

Executive Office
5535 Vine St.
Cincinnati 16, Ohio

Eastern Office
21 West St.
New York 6, N. Y.

A Stacey Brothers 5,000 cu. ft. Wet Seal Gas Holder and 30,000 cu. ft. Stacey-Klonne Dry Seal Gas Holder installed in an Ohio city.

Stacey Brothers GAS HOLDERS

ENGINEERS • FABRICATORS • RECOGNIZED EXPERIENCE & FACILITIES

54" pipe—Spring Lake, N. J.

FLANGED PIPE

FLEXIBLE JOINT PIPE

BELL & SPIGOT PIPE

SPECIAL CASTINGS

SHORT BODY BELL & SPIGOT SPECIALS

Large stock enables us to make prompt shipments.

CAST IRON PIPE

SIZES 2" TO 84"

Warren Foundry & Pipe Corp.

11 Broadway, New York

Warren Pipe Company of Mass., Inc.

75 Federal St., Boston

Steel Co. have been awarded the Army-Navy "E". J. Leslie Brown is president of the company, Gairald H. Garrett is vice president and general manager, and Norval J. Thompson is secretary and sales manager.

O'Connor Exec. Vice Pres. of Dresser

The Dresser Manufacturing Co. has announced the election of three vice presidents of the company following a recent meeting of the Board of Directors.

J. B. O'Connor has been elected

J. B. O'Connor

Executive Vice President. Arthur R. Weis and Lyle C. Harvey have been elected Vice Presidents.

Mr. O'Connor has been a Director of Dresser Manufacturing Co. since August 23, 1938. He is also Vice President and General Sales Manager of Clark Brothers; Chairman of the Board of the Pacific Pump Works; and President of Bovaird and Seyfang, all subsidiaries of Dresser Manufacturing Co.

Mr. Weis is President of the Pacific Pump Works of Huntington Park, California, a Dresser subsidiary. Mr. Harvey is President of the Bryant Heater Co. of Cleveland, also a subsidiary. C. P. Clark, President of Clark Brothers, who is already a Vice President of Dresser Manufacturing Co. will continue to serve in that capacity.

90 Years of Tank Fabrication R. D. Cole Co.'s Record

On May 7 the R. D. Cole Manufacturing Co. of Newnan, Ga., manufacturers of tanks and towers, celebrated the 90th anniversary of the founding of the company. Recently the company received the Gold Star Award of Merit from the Maritime Commission to add to the "M" pennant which has flown over the Cole plant for sometime now.

Le Roy Evans Mueller's New Eastern Manager

Announcement has been made that Le Roy J. Evans, Philadelphia representative of Mueller Co. of Decatur, Ill., and Chattanooga, Tenn., has been

L. J. Evans

appointed Eastern Sales Mgr. for the company. Mr. Evans will be located in New York City with headquarters at 350 Fifth Ave., and will continue to cover the Philadelphia territory in addition to the eastern seaboard.

LITERATURE AND CATALOGS

Aquatic Weed Control is a pictorial report on control of weeds in drainage and irrigation systems. Issued by the Chloroben Corp. of Jersey City, and complete with pictures showing before and after conditions, and methods of application of Chloroben, accompanied by explanatory text, this brochure gives interesting and helpful information on aquatic vegetation control.

Included in the material is a discussion of Benochlor research, field tests, directions for application practice, as well as information on emergent vegetation and what to do about it. For this book on aquatic weed control, write to the Chloroben Corp., Jersey City 2, New Jersey.

"All-Service Gas Masks" are shown in two models in a folder from Mine Safety Appliances Co., Pittsburgh. Model S and the Standard Model are both equipped with the M.S.A. "All-Vision" Facepiece. The folder shows each model, and a keyed diagram shows the location of each part. Prominent among the features of the "All-Service" mask is an automatic timer which indicates the service time undergone by the canister. There is also shown an "All-Vision" type speaking diaphragm facepiece which permits clear, resonant, transmission of speech. This new folder

For Wartime Maintenance of Water Works and Sewage Plants

Inertol coatings often protect concrete and steel structures *for years* without repainting. Result of 40 years' research, each was developed to provide specific protection against salt or fresh water, chemicals, weather or soil. All are in wide use today in water works and sewage plants, on reservoirs, and tanks, structural steel, piping, machinery, building interiors and exteriors and other exposed surfaces. INERTOL COMPANY, INC., 470 FREYLINGHUYSEN AVENUE, NEWARK 5, N. J. AND 64 SOUTH PARK, SAN FRANCISCO, CALIF.

Inertol — Waterproofing and protective coatings for concrete and steel under ground or water or in damp atmosphere.

Ramuc — Waterproof, acidproof finish for concrete and masonry walls, floors and ceilings.

Rigortex — Synthetic resin enamel for serious metal corrosion problems, even when involving occasional submersion.

Glamortex — Tough, resilient, glossy coating for steel and wood in average conditions indoors or out. Ideal for machinery.

Pluvol — Colorless, water-repellent coating for exterior stucco, brick, concrete, to prevent penetration of dampness.

INERTOL PROTECTIVE COATINGS

Let us send you
FOLDER NO. 590
(*Water Works*)
FOLDER NO. 588
(*Sewage Plants*)

Motor Operated Gate Valve

SAVE MANPOWER!

The need for conserving manpower is currently stressed due to war-time conditions. This has influenced the use of motor operated valves on many war projects.

After the war, you may find it well worth-while to consider using these valves in your water plant where frequent operation is necessary.

RENSSELAER VALVE CO., Troy, N. Y.

THE NEW
ENSLOW STABILITY INDICATOR

Completely redesigned to embody improvements suggested and developed by practical water works men under actual plant operating conditions.

Conceived by L. H. Enslow, this apparatus provides a continuous index of corrosivity or stability of water, with nothing more involved than alkalinity filtrations and no complicated calculations.

In operators' opinions **"an invaluable aid"** in the control of stabilization and anti-corrosion treatment.

Write for descriptive literature.

PHIPPS & BIRD, INC.
POST OFFICE BOX 586
RICHMOND 5, VA.

"SOUTHERN CENTER FOR LABORATORY APPARATUS AND CHEMICALS"

Don't Wait
tell us now!

Our representatives will soon be calling upon you and renewing old friendships. We are gradually getting into position to release them for at least part-time travel.

But please don't wait. Now is the time for a seasonal check-up of your water works requirements.

Our real job is producing specialized items for our armed forces on the fighting fronts, but we are also producing Water Works Materials for the home front. You can help us immensely by getting your orders in early, so that we can provide you with enough and on time.

LET'S ALL BACK THE ATTACK—BUY WAR BONDS

OUR SEVENTY-FIFTH ANNIVERSARY

COPPER • BRASS • LEAD • IRON

HAYS *Water Works* PRODUCTS

HAYS MFG. CO., ERIE, PA. • *Since 1869*

showing these various improved masks and accessories may be obtained by writing the Mine Safety Appliances Co., Pittsburgh, Pa.

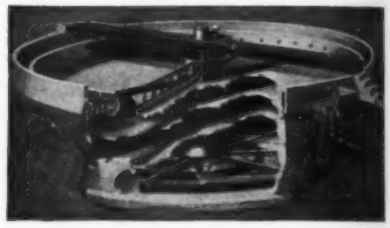
Vibrating Screens for Industrial Wastes. A new, 8-page, illustrated brochure on Liquid Vibrating Screens for recovering waste products and effectively reducing pollution, comes from Link-Belt Company.

Originally introduced by Link-Belt for removing cuttings, shale and sand from rotary oil well drilling mud, it is said that hundreds of these screens are now in successful use in this service, as well as in extracting solids from industrial waste waters, sludge, sewage, oils and other liquids.

The new book contains numerous photographs of actual installations, and gives construction details, dimensions and weights of the various sizes of screens available for this type of service.

A copy of Book No. 1977 may be obtained by writing direct to Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, or other offices of the company.

The Burgess Noise Snubbing Principle is presented in Bulletin No. 430 describing the Snubbers of the Burgess-Manning Co. of Chicago. This bulletin describes how these snubbers prevent exhaust noise with-

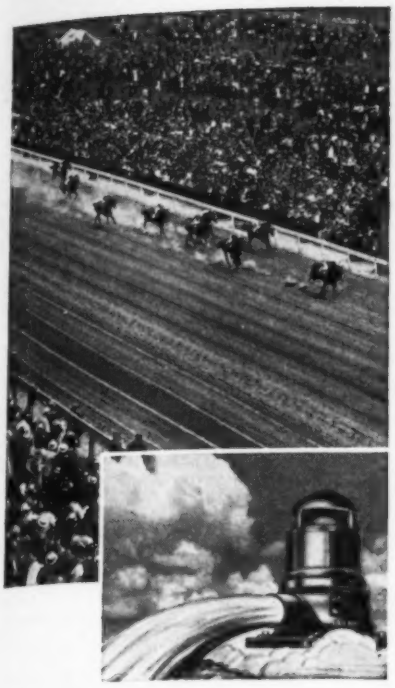


P.F.T. Clarifiers for Rapid Precipitation of Sewage Solids

The P.F.T. Tray Clarifier embodies a design which affects the continuous rapid separation of the solids and liquid in sewage; and the immediate removal of the clarified effluent. A series of shallow settling areas over which the sewage is spread assures speedy precipitation. Its high rate of flow provides maximum capacity in minimum space; reducing the construction and operating costs of clarification equipment.

Write for Bulletin No. 210 containing complete information, including operating results.

P.F.T. **Pacific Flush-Tank Company**
4241 Ravenswood Ave., Chicago, Ill.
New York Charlotte, N. C.



WINNERS

MUST HAVE QUALITY . . . AND ENDURANCE

Maybe you didn't have your money on the winner in the 70th Kentucky Derby! Maybe you couldn't pick a horse like Pensive from a field of 16 starters. But one thing you did know—and have always known—is that it takes quality and endurance to win in any race.

In buying your postwar Water System, you had better remember the quality-endurance formula. You can't afford to own an "also ran" water system when the days of war are over and peace is here again.

You can put your money square on the "nose" of a Layne Water System — and always win. You will win on quality and endurance. You will get large quantities of water at low cost. You will get dependable performance year in and year out. And you will get a mighty big reward in knowing that you own the world's finest and most efficient Water System.

Right now is a good time to make preliminary plans. You can secure the aid of Layne Engineers without obligation. You can get set for the days of peace. Late literature will be helpful. Address Layne & Bowler, Inc., General Offices, Memphis 8, Tennessee.

AFFILIATED COMPANIES: Layne-Arkansas Co., Stuttgart, Ark. ★ Layne-Atlantic Co., Norfolk, Va. ★ Layne-Central Co., Memphis, Tenn. ★ Layne-Northern Co., Mishawaka, Ind. ★ Layne-Louisiana Co., Lake Charles, La. ★ Louisiana Well Co., Monroe, La. ★ Layne-New York Co., New York City ★ Layne-Northwest Co., Milwaukee, Wis. ★ Layne-Ohio Co., Columbus, Ohio ★ Layne-Texas Co., Houston, Texas ★ Layne-Western Co., Kansas City, Mo. ★ Layne-Western Co. of Minnesota, Minneapolis, Minn. ★ International Water Supply Ltd., London, Ontario, Canada

LAYNE

WELL WATER SYSTEMS

DEEP WELL PUMPS

BUILDERS OF WELL WATER SYSTEMS FOR INDUSTRIES AND MUNICIPALITIES

out affecting engine performance. Originally developed for the Diesel engine the Burgess Snubber may also be applied to any engine which exhausts in "slugs." Catalog No. 435 and Bulletin 447 are companion catalogs showing the design, installation and specifications of these exhaust snubbers for various combustion engines. For copies write Burgess-Manning Co., 2815 W. Roscoe St., Chicago, Ill.

Schramm Fordair Compressors, the No. 60 type, are illustrated in complete detail in various mountings in Catalog 4215 of Schramm, Inc., of West Chester, Pa. These mountings include trailer types, skid mountings, Tampair, Trailbuilder, Railcar, Powair, shipping units, and stationary models. Recommended tools are shown, as are dimensions and weights. Catalog 4215 may be obtained from Schramm, Inc., West Chester, Pa.

Simplex Air Inlet Valves in Bull. No. 125 of the Simplex Valve and Meter Co. of Philadelphia. This 12 page bulletin contains information on the use of air inlet valves for the protection against collapse of thin-walled gravity flow lines. In addition to a presentation of how

LEADITE

The Pioneer Self-Caulking Material for C.I. Pipe

Be positive;

it is LEADITE

More miles of C. I. bell and spigot water pipe have been jointed with *Leadite* than any other melted, self-caulking material . . . Also, Leadite has seen more years of service.

THE LEADITE COMPANY
Girard Trust Co. Bldg., Philadelphia 2

No Caulking

EDDY

FIRE HYDRANTS AND VALVES

WATER WORKS EQUIPMENT

EDDY VALVES
For
Water Works
and
Sewage Disposal
Plants

EDDY FIRE HYDRANTS
For Fire Protection Service

Write for Complete Catalog

Eddy
VALVE COMPANY
WATERFORD, N. Y.

INCINERATION ENGINEERS

NICHOLS ENGINEERING & RESEARCH CORPORATION

60 WALL TOWER NEW YORK, N. Y.

Consultants • Designers • Constructors

Cuts pipe in the trench!

Cast Iron Pipe

Cutters

Have Given Years of Dependable Service

A particularly adaptable tool for the water works field.

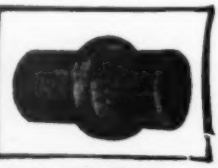
4 inch to 24 inch

Send for bulletin and prices

THE TUCKER COMPANY, INC.
Sole Manufacturers. 75 Murray St., N.Y.C.

to determine air inlet size and methods of preventing collapse as well as a discussion of the collapsing pressure of pipe, this bulletin contains four nomographs of value. These include a means of determining the collapsing pressure, the determination of the required size and number of air inlet valves, the determination of size and other characteristics for differentials above the critical pressure, and the exit flow of air from a pipe when filling the line.

WESTON



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In addition, the operation and construction of the valves are described and a practical application discussed. Installation diagrams are likewise included along with suggested specifications. A combination air inlet and air release is also shown. Further information on this Bull. No. 125 may be obtained by addressing a request to the Simplex Valve and Meter Co., 69th and Upland Sts., Philadelphia 42, Pa.

Preload Concrete is subject of a new illustrated eight-page bulletin which explains in detail the advantages of the Preload Method of prestressing concrete in economical weight-saving construction. An interesting comparative table is included showing the savings in steel for storage tanks of various capacities that are effected by the Preload System. The system has found application for municipal or industrial water tanks, chemical tanks, conduits, canals, sewage disposal plant units and other structures where crackless, durable concrete is. A copy of the Bulletin will be sent on request to The Preload Co., 420 Lexington Ave., New York 17, N. Y.

In **Lead** for March and April, 1944, published by the Lead Industries Association, is a story on the rechargable pocket flashlight bat-

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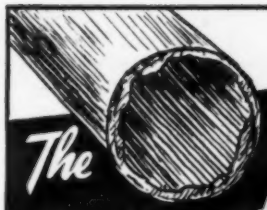
tery produced by the Ideal Commutator Dresser Co. of Sycamore, Ill. This story has been told here before but it bears repeating. Pointing out that this long desired flashlight battery has at last been produced, the article mentions that the lead-acid battery is perfectly safe from leakage, will operate in any position, and is easily charged by means of a simple, inexpensive charging unit attached to any AC electric outlet. Inasmuch as a single lead cell produces only two volts, a special two volt lamp is required in place of the three volt lamp commonly used with the two cell dry flashlight battery. Further information on this battery may be obtained from the Ideal Commutator Dresser Co., Sycamore, Ill.

The Yeomans Guard for March-April carries a story on a new ejector which handles muck, hay and other bulky wastes. An accompanying photograph shows the installation of one of these ejectors at a packing plant for slaughter house waste and another at the South St. Paul, Minn., Sewage Treatment Works. At this latter location settled domestic sewage, as well as packing house wastes, are handled by the ejector, which discharges over the drying lagoons. The density



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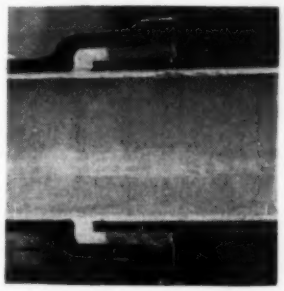

View showing Tate Process in Pipe Joint. Note thoroughness of Lining.

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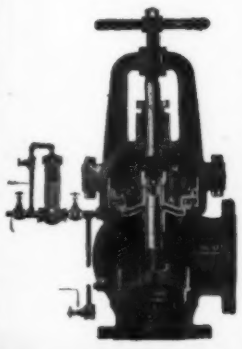

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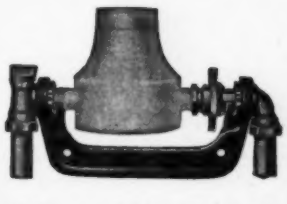

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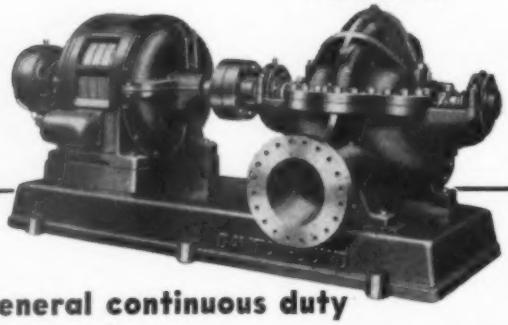

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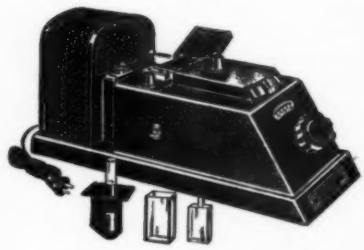

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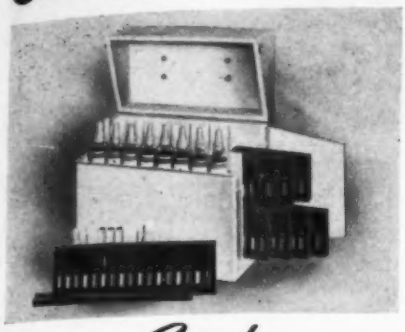

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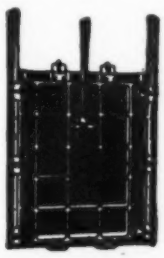

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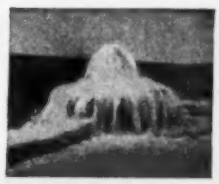

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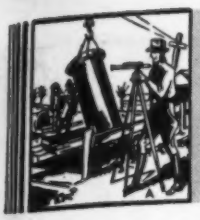

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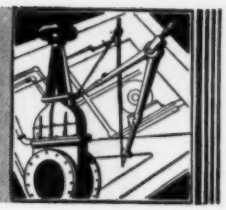

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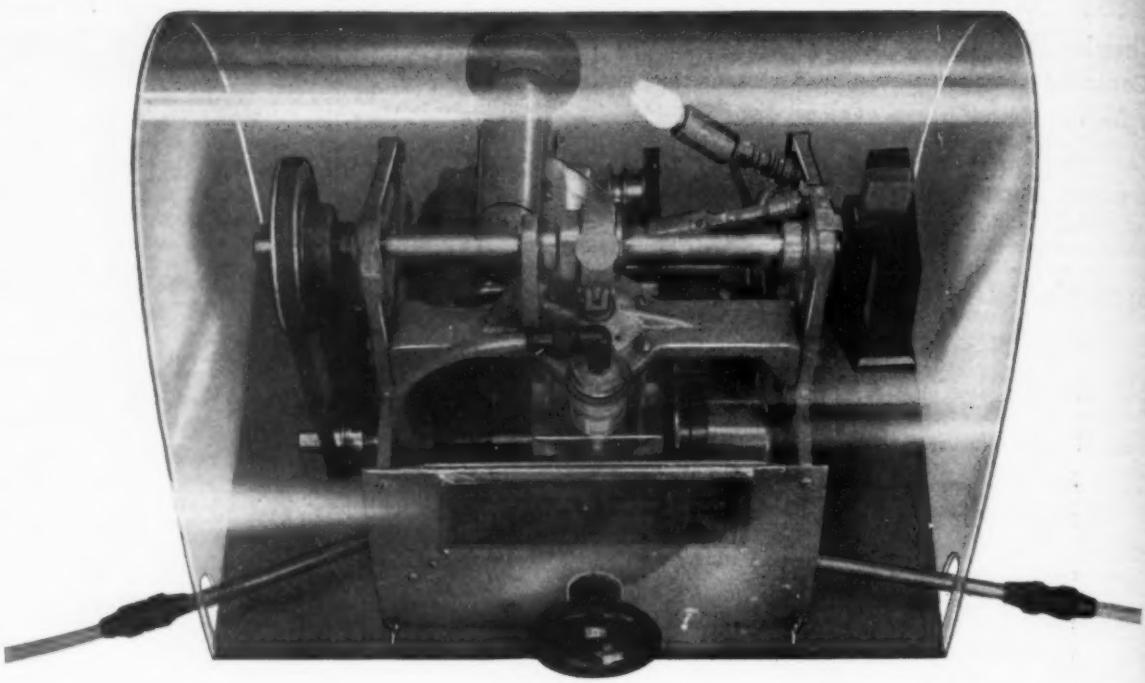
Municipal Engineering and Public Utilities

11 North Pearl Street
Albany 7, New York

3 CHEMICAL FEEDERS IN 1



That's What You Get When You Buy a

3 in 1 VAR-I-FEEDER

Heretofore chemical feeders have been so limited in range of capacity that separate units have been required for extremely low capacities, for standard or average capacities, and for exceptionally high capacities, respectively.

Now one machine,—the new 3 in 1 Var-I-Feeder,—suffices for all three purposes. Starting with a STANDARD-speed feeder, to get a HIGH-speed feeder, reverse one accessible pulley; to get a LOW-speed feeder, change one belt and pulley. Takes only 30 seconds. Table furnished gives reading corrections for abnormal water pressures. Total range of machine, with different pulley arrangements is from less than 1 G. P. H. to 11 gallons per hour, for instance from 1.2 to 5.9 G. P. H. against 40 lbs. pressure or from 1.8 to 11. G. P. H. against 0 pressure.

OTHER FEATURES

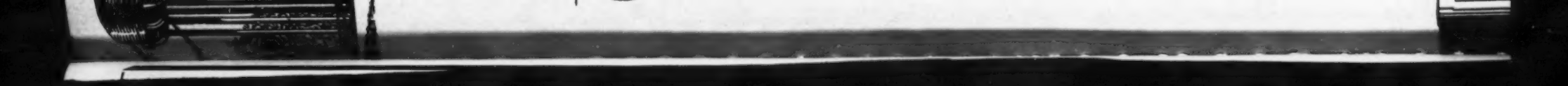
Hand wheel adjustment of rate of feed, while machine is running. Illuminated indicator dial, showing rate of feed. Dependable constant rate of feed at any hand wheel setting. Water meter controlled unit if desired. Illuminated "Clear-View" plastic, "right-side up" reagent head. Transparent plastic tubing. "Clear-View" transparent plastic case, covering entire machine—dust and splash proof. High capacity gear head motor. Pulley for drive from any available external R. P. M. or gas engine. Accessibility; entire case lifts off. Simple, rugged construction. Compactness—12" by 13" by 18". Light-weight—55 lbs.

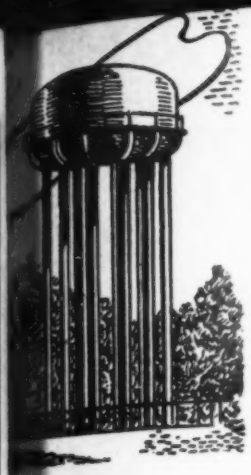
Write for descriptive bulletin.

CHEM-FEEDS, INC.

EQUIPMENT MAKERS AND PROPORTIONEERING ENGINEERS

77 RESERVOIR AVENUE, PROVIDENCE, R. I., U. S. A.





PART 1

WATER SUPPLY

WATER WORKS
& SEWERAGE

REFERENCE & DATA SECTION

1944

INDUSTRIAL CHEMICAL SALES

Division West Virginia Pulp & Paper Company

230 PARK AVE., NEW YORK 17, N. Y.

Branch Offices:

35 E. WACKER DRIVE
CHICAGO 1, ILL.

748 PUBLIC LEDGER BLDG.
PHILADELPHIA 6, PA.

844 LEADER BLDG.
CLEVELAND 14, OHIO

AQUA NUCHAR ACTIVATED CARBON FOR WATER TREATMENT

Since the first successful application of activated carbon in powdered form 14 years ago, the acceptance by water plant operators of this method of combating tastes and odors has been so general that at present over 1,200 water plants have used AQUA NUCHAR.

AQUA NUCHAR is a fine black powder having tremendous internal and external surface, for the adsorption of taste and odor bodies from water. It has been scientifically estimated that one cubic inch offers a total external and internal surface of 20,000 square yards. When activated carbon is placed in water containing impurities, these impurities are attracted to the surface of the carbon, much the same as a magnet attracts iron filings. All of these impurities are retained in the carbon, and subsequently are eliminated when the carbon is removed on the filter sand or by settling. The action of activated carbon is therefore a physical rather than a chemical one, and an overdose can have no ill effects, such as may be encountered with the usual water works chemicals.

AQUA NUCHAR has successfully controlled tastes and odors, some of which have been characterized as:

Earthy	Fishy
Woody	Marshy
Vegetable	Swampy
Bitter	Muddy
Aromatic	Chlorine

which may originate from decaying vegetation; Algae, such as synura, synedra, asterionella, uroglena, etc.; and Industrial trade wastes, such as phenols, solvent, volatile oils, etc.

AQUA NUCHAR is effective as a dechlorinating medium and is thus utilized where prechlorination or superchlorination is practiced.

Realizing that taste and odor troubles come suddenly in water plants, we have spotted stocks of AQUA NUCHAR at strategic points throughout the country in storage warehouses. You can feel assured that your order will receive immediate attention and you will be very agreeably surprised at the prompt service we can give you. Experts — from our Technical Service Department are available to study your taste and odor problems, no cost nor obligation.

The sterilization of water supplies by treatment with chlorine has been almost universally adopted as a means of rendering water safe for human consumption. With the development of the use of activated carbon in water works practice it is now possible to deliver a palatable as well as safe water to the consumers. THE COST OF TREATMENT IS MINOR WHEN IT IS CONSIDERED THAT WITH THE AVERAGE DOSAGES BEING APPLIED THE EXPENSE WORKS OUT TO ONLY THREE CENTS PER CAPITA PER YEAR.

"next to knowing - - - - is knowing where to find knowledge"

Foreword

We take especial pride, as publishers, in presenting this volume—the Reference and Data Number of WATER WORKS AND SEWERAGE for 1944.

This section prepared by the Editor and Dr. George E. Symons, Associate Editor, with the aid of John C. Black, Managing Editor, presents the equivalent of a data handbook for designing engineers, managers, and operators of water works and sewerage systems.

The information contained herein has been carefully selected from past issues of WATER WORKS AND SEWERAGE and other sources named in the text. In addition, considerable effort has been made to present the most economical and modern methods, and the latest tables and charts useful to water and sewage works operators and designers.

Even though supplied at no charge to subscribers, beyond the regular subscription fee, the same conscientious work has been put into the preparation of this Data Section as would be expected in a book devoted exclusively to the same type of material and published separately.

* * *

Note

Governmental restriction on the use of paper makes it impossible to include as much material as we should like in this issue. In the past we have repeated useful basic data—tables, graphs, etc.—from year to year, chiefly for the benefit of new subscribers; certain other matter was repeated in alternate years; and new material was, of course, added. Thus the subscriber who kept two consecutive Reference and Data issues on file had all the most important reference material published by Water Works and Sewerage.

In view of current limitations, we have decided this year to publish none of the matter which appeared in 1943, but instead to augment the news articles with material from 1942 and previous issues, in the belief that by so doing we will best serve the majority of readers. We hope that the year 1945 will permit a more liberal use of paper and the presentation of a more complete manual.

L. H. Enslow

Editor.

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FOR THE INDEX TO THE REFERENCE AND DATA MATERIAL, AND THE INDEX TO ADVERTISERS, SEE THE REAR OF THIS SECTION

CLASSIFIED INDEX of PRODUCTS

ABRASIVES
Carborundum Co., Niagara Falls, N. Y.

ACID, SULPHURIC AND HYDROCHLORIC
Dow Chemical Co., Midland, Mich.
General Chemical Co., 40 Rector St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.

ACTIVATED AND BLACK ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.

ACTIVATED CARBON
Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Norit Co., Jacksonville, Fla.
Cliffs Dow Chemical Co., Marquette, Michigan.
Darco Corporation, 60 E. 42nd St., New York City 17.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Industrial Chemical Sales Division, West Virginia Pulp & Paper Co., 230 Park Ave., New York City 17.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Stuart Brumley Corp., Baltimore, Md.

AERATION APPARATUS
Allen Billmyre Corp., 449 Fayette Ave., Mamaroneck, N. Y.
Aluminum Co. of Amer., Gulf Bldg., Pittsburgh, Pa.
The American Well Works, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2340 Wolfram St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Lombard Governor Corp., Ashland, Mass.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

AGITATORS
Allen-Billmyre Corp., 449 Fayette Ave., Mamaroneck, N. Y.
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
The Elmco Corp., P. O. Box 300, Salt Lake City, Utah.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Lombard Governor Corp., Ashland, Mass.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Omega Mach. Co., Inc., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
H. K. Porter Co., Inc., 49th and Harrison Sts., Pittsburgh, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Brumley Corp., Baltimore, Md.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Vogt Mfg. Co., Louisville, Ky.

AIR BLOWERS
(See Blowers, Air)

AIR COMPRESSORS
(See Compressors, Air)

ALLOY CAST IRON PIPE AND FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

ALTERNATORS, ELECTRIC
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.

ALUM, AMMONIA
Innis-Speiden & Co., 117 Liberty St., New York City.

ALUM, BLACK
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Stuart Brumley Corp., Baltimore, Md.

ALUM FILTER COMMERCIAL IRON-FREE
(See Filter Alum)

AMMONIA, ANHYDROUS & AQUA
General Chemical Co., 40 Rector St., New York City.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Mathieson Alkali Wks., Inc., 60 E. 42nd St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.

AMMONIATORS
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Omega Mach. Co., Inc., 3409 E. 18th, Kansas City, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I. (Aqua)
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

ANALYTICAL WARE
Carborundum Co., Niagara Falls, N. Y.
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Phipps & Bird, Inc., Sixth & Byrd Sts., Richmond, Va.

ANTHRAFILT
Anthracite Equipment Corp., 101 Park Ave., New York City.

AQUA AMMONIATORS
(See Ammoniators)

AQUAPHONES
Aqua Survey & Instrument Co., 1409 Marlowe Ave., Cincinnati, Ohio.
Northrop & Co., Inc., 50 Church St., N. Y., N. Y.

ARRESTERS, FLAME
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Vapor Recovery Systems, 2820 N. Alameda St., Compton, Calif.

ASBESTOS-CEMENT PIPE
Johns-Manville Co., 22 E. 40th St., New York City.

ASH AND COAL HANDLING MACHINERY
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.

AUTOMATIC FILTER AND SOFTENER CONTROLS
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

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Link-Belt Speeder Corp., 301 W. Pershing Rd., Chicago 9, Ill.

BAR SCREENS
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

BASE-EXCHANGE SILICATE
(See Ion Exchange Material)

BASIN CLEANERS
Champion Corp., Hammond, Ind.
W. H. Stewart, P. O. 767, Syracuse, N. Y.

BEARINGS, ROLLER & BALL
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 519 N. Holmes Ave., Indianapolis 6, Ind.

BELTS, SAFETY
Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

BINS, STORAGE
Chain Belt Co., Milwaukee, Wis.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
National Fireproofing Corp., 202 E. Ohio St., N. S., Pittsburgh, Pa.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

BITUMINOUS COATINGS AND LININGS
(See also Cement Linings)
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

BLACK ALUM
Activated Alum Corp., Curtis Ba., Baltimore, Md.
Stuart Brumley Corp., Baltimore, Md.

BLEACHING POWDER
Hood Chemical Co., 450 W. 31st St., New York City.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Grant Bldg., Pittsburgh 19, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.
O. S. Tyson & Co., Inc., 230 Park Ave., New York, New York.

BLOWERS, AIR (Centrifugal and Rotary)
Allen-Billmyre Corp., 449 Fayette Ave., Mamaroneck, N. Y.
De Laval Steam Turbine Co., Trenton, N. J.
Roots-Connersville Blower Corp., Connersville, Ind.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

BLOWERS (Gasoline Engine Driven Portable)
Allen-Billmyre Corp., 449 Fayette Ave., Mamaroneck, N. Y.
Homelite Corporation, Port Chester, N. Y.

BOILER BLOWOFF APPARATUS
Permutit Co., 330 W. 42nd St., New York City.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

BOILER FEED PUMP CONTROL
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

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The American Well Works, Aurora, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron, Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., The, Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 301 W. Pershing Rd., Chicago 9, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 3409 E. 18th St., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Penn.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthington Pump & Machinery Corp., Harrison, New Jersey.
Zeolite Chemical Co., 140 Cedar St., New York City.

BOILER FURNACE, BRICK
Carborundum Co., Perth Amboy, N. J.

BOILER PLANT ACCESSORIES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Photoswitch, Inc., 21 Chestnut St., Cambridge, Mass.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

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American Radiator & Standard Sanitary Corp., Bessemer Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

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John Wiley & Sons, Inc., 440 4th Ave., New York 16, N. Y.

BOXES, VALVE AND METER
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Ford Meter Box Co., Wabash, Ind.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

BRAKES, MAGNETIC, MECHANICAL, HYDRAULIC
The Clark Controller Co., 1146 East 152nd St., Cleveland, Ohio.

BRASS GOODS
(See also Pipe, Brass.)
American Brass Co., Waterbury, Conn.
Bridgeport Brass, Bridgeport 2, Conn.
Crane Co., 836 S. Michigan Ave., Chicago.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

BREATHING APPARATUS
Mine Safety Appliance Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

BREECHINGS, STEEL
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BUCKETS, SEWER
Champion Corp., Hammond, Ind.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

BUFFER SOLUTIONS & MIXTURES
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

BUTTERFLY VALVES
(See Valves, Butterfly)

CALCIUM HYPOCHLORITE
(See also Bleaching Powder)
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Hood Chemical Co., 450 W. 31st St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Grant Bldg., Pittsburgh 19, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
E. M. Sergeant Pump & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.

CALGON (See Corrosion Suppression and Water Stabilization)

CALKING MACHINES & TOOLS
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Schramm, Inc., West Chester, Pa.

CARBON-ACTIVATED
(See Activated Carbon.)

CARBONATORS (Recarbonation).
Carborundum Co., Perth Amboy, N. J.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

CAR SPOTTERS & HAULAGE SYSTEMS
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
The Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Chain Belt Co., Milwaukee, Wis.
Climax Engineering Co., Clinton, Iowa.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hunt, Rodney, Machine Co., Orange, Mass.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
M & H Valve & Fittings Co., Anniston, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

CAST IRON PIPE
(See Pipe.)

CATCH BASIN INLET
Northrop & Co., Inc., 50 Church St., New York City.

CATCH BASINS, CORRUGATED IRON
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.

CATHODIC PROTECTIVE SYSTEMS
Electro Rust-Proofing Co., 1026 Wayne Ave., Dayton, Ohio.

CAUSTIC SODA
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Hood Chemical Co., 450 W. 31st St., New York City.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.
Solvay Sales Corp., 40 Rector St., New York City.

CEMENT, ASBESTOS PIPE
Johns-Manville, 22 E. 40th St., New York City.

CEMENT GUN
Cement Gun Co., Allentown, Pa.

CEMENT PIPE
(See Pipe, Cement; Pipe, Concrete.)

CEMENT LINED PIPE
(See Pipe.)

CEMENT LINING OF PIPE
Cement Lined Pipe Co., Lynn, Mass.
Centriline Corp., 140 Cedar St., New York City.
Tate Pipe Linings, Inc., Andover, Mass.

CEMENTS, ACID PROOF
Atlas Mineral Prod. Co., Mertztown, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.

CEMENTS, REFRACTORY
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

CEMENTS, SEWER PIPE
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.

CEMENTS, WATER MAINS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Girard Trust Bldg., Philadelphia, Pa.

CHAINS (Elevating, Conveying & Power Transmission)
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

CHEMICAL CONVEYING EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

CHEMICAL FEEDING & PROPORTIONING EQUIPMENT
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold, 422 First Ave., Pittsburgh, Pa.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Omega Machine Co., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.

Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CHEMICALS FOR WATER PURIFICATION

Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Colloid Co., 363 W. Superior St., Chicago, Ill.
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Darco Corp., 60 E. 42nd St., New York City 17.
Diamond Alkali Co., Pittsburgh, Pa.
The Dow Chem. Co., Great Western Div., 310 Sansome St., San Francisco, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hooker Electrochemicla Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Industrial Chemical Sales Div West Virginia Pulp & Paper Co., 230 Park Ave., New York 17.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Innis-Speiden & Co., 117 Liberty St., New York City.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Mathieson Alkali Works, Inc., 60 E. 42nd St., New York.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
National Lime Assn., 927 Fifteenth St. N. W. Washington, D. C.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Reilly Tar Chem. Corp., Merchants Bank Bldg., Indianapolis, Ind.
L. A. Salomon & Bro., 216 Pearl St., New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.
Solvay Sales Corp., 40 Rector St., New York.
Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.
Stuart Brumley Corp., Baltimore, Md.
Tamms Silica Co., 228 N. LaSalle St., Chicago, Ill.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CHEMISTS AND ENGINEERS

(See Directory of Consultants, pages 136 & 137).

CHLORIDE OF LIME (Chlorinated Lime)

Hood Chemical Co., 450 W. 31st St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.

CHLORINATORS

(See also Hypochlorinators.)
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 3409 E. 18th, Kansas City, Missouri.
Phipps & Bird, Inc., Sixth & Byrd, St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CHLORINE DIOXIDE

(See Sodium Chlorite)

CHLORINE, LIQUID

Diamond Alkali Co., Pittsburgh, Pa.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Hooker Electro Chemical Co., Niagara Falls, N. Y.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Grant Bldg., Pittsburgh 19, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.
Solvay Sales Corp., 40 Rector St., New York.
Wallace & Tiernan, Inc., Newark 1, N. J.

CHLORINE CONTROL EQUIPMENT

Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Omega Machine Co., 3409 E. 18th, Kansas City, Missouri.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

CHUTES, COAL, ETC.

Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CLAMPS AND SLEEVES, PIPE

Amer. Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

CLAMPS, BELL JOINT

Carson-Cadillac Corp., Birmingham, Ala.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Northrop & Co., Inc., 50 Church St., New York City.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

CLAMPS, PIPE REPAIR

Carson-Cadillac Corp., Birmingham, Ala.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Northrop & Co., Inc., 50 Church St., New York City.

CLARIFIERS, SEWAGE AND WATER

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Nichols Engineering & Research Corp., 40 Wall St., New York, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

CLEANING SEWER MAINS

Champion Corp., Hammond, Ind.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 30 Church St., New York City.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

CLEANING WATER MAINS

Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 30 Church St., New York City.
Stuart Brumley Corp., Baltimore, Md.
Tate Pipe Linings, Inc., Andover, Mass.

COAGULANTS & COAGULATION CONTROL CHEMICALS

Activated Alum Corp., Curtis Bay, Baltimore, Md.
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Graver Tank & Mfg. Co., East Chicago, Indiana.
Innis-Speiden & Co., 117 Liberty St., New York City.
Lakeside Enigneering Corp., 222 W. Adams St., Chicago, Ill.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Philadelphia Quartz Co., 124 S. Third St., Philadelphia 6, Pa.
Stuart Brumley Corp., Baltimore, Md.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

COAL & ASHES HANDLING MACHINERY

(See Ash & Coal Handling Machy.)

COATINGS, ACID & ALKALI-PROOF FOR CONCRETE, STEEL AND WOOD

Atlas Mineral Products Co., Mertztown, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
The Elmco Corp., P. O. Box 300, Salt Lake City, Utah.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

COATINGS AND LININGS

(See Bituminous Coatings and Linings.)

COCKS, CURB, METER, CORPORATION, ETC.

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Merco Nordstrom Valve Co., Lexington Ave., Pittsburgh, Pa.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

COLLECTORS (Sludge)

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.

COMBUSTION INDICATORS AND RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Fischer & Porter Co., Hatboro, Pa.
Photoswitch, Inc., 21 Chestnut St., Cambridge, Mass.
Permutit Co., 330 W. 42nd St., New York City.

COMMINUTORS

(See Grinders also)
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

COMPARATORS

Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

COMPOUNDS, SEWER JOINT

Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Reilly Tar & Chem. Corp., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

COMPRESSORS, AIR

Cooper-Bessemer Corp., Mount Vernon, Ohio.
De Laval Steam Turbine Co., Trenton, N. J.
Gardner-Denver Co., Quincy, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Roots-Connersville Blower Corp., Connersville, Ind.
Schramm, Inc., West Chester, Pa.
Sullivan Machinery Co., Michigan City, Indiana.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Machinery Corp., Harrison, New Jersey.
Yeoman Brothers Co., 1433 Dayton St., Chicago 22, Ill.

CONCRETE BREAKERS

Gardner-Denver Co., Quincy, Ill.
Schramm, Inc., West Chester, Pa.
Sullivan Machinery Co., Michigan City, Indiana.

CONCRETE CONTROL

Scientific Concrete Service Corp., McLachlen Bldg., Washington, D. C.

CONCRETE HARDENER

Connelly Iron Sponge and Governor Co., 3154 So. California Ave. Chicago, Ill.
Diamond Alkali Co., Pittsburgh, Pa.
Philadelphia Quartz Co., 124 S. Third St., Philadelphia 6, Pa.
Sika, Inc., Passaic, N. J.
Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.

CONCRETE MIXERS

Chain Belt Co., Milwaukee, Wis.

CONCRETE PIPE

(See Pipe, Concrete.)
American Concrete Pipe Assn., 33 W. Grand Ave., Chicago 10, Ill.
Lock-Joint Pipe Co., Ampere, N. J.

CONDENSERS (Steam)

Amer. Cast Iron Pipe Co., Birmingham, Ala.
J. P. Devine Mfg. Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
U. S. Pipe & Foundry Co., Burlington, N. J.
Worthington Pump & Machy. Corp., Harrison, N. J.

CONTRACTORS (Water Works & Sewerage)

Ambursen Engineering Corp., 295 Madison Ave., New York, N. Y.
Fritz Ziebarth, 820 W. Esther St., Long Beach, Calif.

CONTROLLERS, AUTOMATIC, ELECTRIC

Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Fischer & Porter Co., Hatboro, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CONTROLLERS, FLOW, LEVEL, PRESSURE, TEMPERATURE

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Fischer & Porter Co., Hatboro, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York, N. Y.
Photoswitch, Inc., 21 Chestnut St., Cambridge, Mass.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Turbine Equipmnet Co., 75 West St., Ne wYork 6, N. Y.
Wallace & Tiernan Co., Inc., Newark, 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CONVEYORS AND CONVEYING EQUIPMENT

Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis.
Jeffrey Mfg. Co., Columbus, Ohio
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Omega Machine Co., 3409 E. 18th St., Kansas City, Mo.

COOLING TOWERS

J. P. Devine Mfg. Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.

COPPER, BRASS, BRONZE

American Brass Co., Waterbury, Conn.
Bridgeport Brass Co., Bridgeport 2, Conn.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.

COPPERAS (Sulphate of Iron)

Innis-Speiden & Co., 117 Liberty St., New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.

COPPER SULPHATE

General Chemical Co., 40 Rector St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

COPPER TUBE, FLEXIBLE

American Brass Co., Waterbury, Conn.
Bridgeport Brass Co., Bridgeport 2, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill

CORROSION SUPPRESSION

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.

COUPLINGS & CONNECTIONS, PIPE

Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
National Tube Co., Frick Bldg., Pittsburgh, Pa.
Peerless Pump Division, Food Machinery Corp., 301 West Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

COUPLINGS, FLEXIBLE

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave. Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Dresser Mfg. Co., Bradford, Pa.
Jeffrey Mfg. Co., Columbus, Ohio
Link-Belt Co., 220 S. Belmont Ave., Indianapolis 6, Ind.
Lombard Governor Corp., Ashland, Mass.
Peerless Pump Division, Food Machinery Corp., 301 West Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa

COVERS, HANDHOLE, MANHOLE, SAMPLING

Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Nooter, John, Boiler Works Co., 1410 2nd St., St. Louis 4, Mo.
Northrop & Co., Inc., 50 Church St., New York City.
United Concrete Form Products Co., 5243 W. 25th Pl., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

CRANES & HOISTS

Hunt, Rodney, Machine Co., Orange, Mass.
Link-Belt Speeder Corp., 301 W. Pershing Rd., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

CULVERT CLEANERS

Champion Corp., Hammond, Ind.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

CULVERT PIPE

American Cast Iron Pipe Co., Birmingham, Ala.
American Rolling Mill Co., Middletown, Ohio.
American Concrete Pipe Assn., 33 W. Grand Ave., Chicago, Ill.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
The Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City (Asbestos-Cement).
Lock Joint Pipe Co., Ampere, N. J.
U. S. Pipe & Foundry Co., Burlington, N. J. (Cast Iron)
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Philadelphia, Pa.

CURB BOXES

Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

DECHLORINATING EQUIPMENT AND CHEMICALS

Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco., Inc., 325 W. 25th Pl., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

DE-MINERALIZATION (Water)

Dorr Co., 570 Lexington Ave., New York 22, N. Y.

DEMOLITION TOOLS

Gardner-Denver Co., Quincy, Ill.
Schramm, Inc., West Chester, Pa.
Sullivan Machinery Co., Michigan City, Indiana.

DIAPHRAGM, PUMP

Ralph B. Carter Co., 53 Park Pl. New York City.
The Deming Company, Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

DIESEL ENGINES

(See Engines, Diesel)

DIFFUSERS—PLATES & TUBES

Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

DIGESTERS EQUIPMENT (Sludge)

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
J. P. Devine Mfg. Co., Div. H. K. Porter Co., 49th and Harrison St., Pittsburgh, Pa.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Yeomans Brothers Co., 1433 Dayton, St., Chicago 22, Ill.

DISTRIBUTORS (Filter)

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Yeomans Brothers Co., 1433 Dayton, St., Chicago 22, Ill.

DRIVES, CHAIN

Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

DRIVES, RIGHT ANGLE GEAR

Johnson Gear Co., Berkeley, Calif.

DRY CHEMICAL FEEDERS

(See Chemical Feeding Equipment)

DRYERS, ROTARY

J. P. Devine Mfg. Co., Div. H. K. Porter Co., 49th and Harrison St., Pittsburgh, Pa.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.

ELECTRICALLY OPERATED GATE VALVES

Crane Co., 836 S. Michigan Ave., Chicago.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

ELEVATING AND CONVEYING EQUIPMENT

(See Conveyors & Conveying Equipment.)

ENGINEER TRAINING

Alexander Hamilton Institute, 71 W. 23rd St., New York 10, N. Y.

ENGINEERS AND CHEMISTS

(See Directory of Consultants, pages 136-137.)

ENGINEER'S REPRODUCTION SERVICE

Lithoprint Co. of N. Y., 145 Hudson St., New York, N. Y.

ENGINE GENERATING SETS

Climax Engineering Co., Clinton, Iowa.
De Laval Steam Turbine Co., Trenton, N. J.

Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Homelite Corp., Port Chester, N. Y. (Gasoline Engine Driven and Portable.)
Northrop & Co., Inc., 50 Church St., New York City (Gasoline Driven Portable.)
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, DIESEL

Climax Engineering Co., Clinton, Iowa.
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Schramm, Inc., West Chester, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES (Gas & Gasoline)

Climax Engineering Co., Clinton, Iowa.
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, SLUDGE GAS

Cooper-Bessemer Corp., Mount Vernon, Ohio.
Climax Engineering Co., Clinton, Iowa.
Worthington Pump & Mach. Corp., Harrison, N. J.

EXPANSION JOINTS—PIPE

(See Joints—Expansion, Pipe)

EXHAUSTERS, AIR

(See Vacuum Pump)

FANS, EXHAUST AND VENTILATING

Jeffrey Mfg. Co., The, 968-99 N. 4th St., Columbus 16, Ohio.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

FEED, CHEMICAL

(See Chemical Feeding Equipment.)

FEED WATER FILTERS

Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Turbine Equipment Co., 75 West St., New York 6 N. Y.
Worthington Pump & Machinery Corp., Harrison, N. J.

FEED WATER HEATERS

Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Machy. Corp., Harrison, N. J.

FEED WATER TREATMENT

(See Boiler Feed Water Treatment)

FERRIC CHLORIDE

Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
General Chemical Co., 40 Rector St., New York City.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Innis, Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa. (Liquid)
Wallace & Tiernan Co., Inc., Newark, N. J.

FERRIC CHLORIDE FEEDERS

Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Omega Machine Co., Inc., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

FERRIC SULFATE

Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Tennessee Corp., 621 Grant Bldg. Atlanta, Ga.

FERROUS SULPHATE

General Chemical Co., 40 Rector St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.

FILTER-AIDS

Anthracite Eqpt. Corp., 101 Park Ave., New York City.
Johns-Manville, 22 E. 40th St., New York City. (Celite.)
L. A. Salomon & Bro., 216 Pearl St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., Baltimore, Md.

FILTER ALUM

Activated Alum Corp., Curtis Bay, Baltimore, Md.
General Chemical Co., 40 Rector St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.
Stuart Brumley Corp., Baltimore, Md.

FILTER CLEANING PROCESS

Roberts Filter Mfg. Co., Darby, Pa.
Stuart Brumley Corp., Baltimore, Md.
Virginia Smelting Co., West Norfolk, Va.

FILTER CLOTH

Mercury Technical Cloth & Felt Corp., 1265 Broadway, New York City.

FILTERING EQUIPMENT

The American Well Works, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
R. D. Cole Mfg. Co., Newnan, Ga.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Oliver United Filter, Inc., New York City.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., Baltimore, Md.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Underpinning & Foundation Co., Inc., 155 E. 44th St., New York City (For Sewage)
Worthington Pump & Machinery Corp., Harrison, N. J.

FILTER GRAVEL

(See Gravel, Filter)

FILTER PLATES AND TUBES

Carborundum Co., Perth Amboy, N. J.
N. Y.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.

FILTER RATE CONTROLLERS & GAGES

(See Rate Controllers.)

FILTER SAND

Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Laughlin Equipment Corp., 270 Madison Ave., New York City.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Brumley Corp., Baltimore, Md.
Tamms Silica Co., 228-WS N. La Salle St., Chicago, Ill.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Zeolite Chemical Co., 140 Cedar St., New York City.

FILTER UNDERDRAINS, SEWAGE

The American Well Works, Aurora, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
National Fireproong Corp., 202 East Ohio St., N. S., Pittsburgh, Pa.

FILTER UNDERDRAINS, WATER

Carborundum Co., Niagara Falls, N. Y.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams, Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

FILTER WASH CONTROL

Builders-Providence, Inc., 9 Codding St., Providence, R. I.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

FIRST AID KITS

Mine Safety Appliance Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

FITTINGS, PIPE, SOLDER TYPE

American Brass Co., Waterbury, Conn.
American Smelting and Refining Co., 120 Broadway, N. Y. C.
Bridgeport Brass Co., Bridgeport 2, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.

FITTINGS, TEES, ELLS, ETC.

American Brass Co., Waterbury, Conn.
American Cast Iron Pipe Co., Birmingham, Ala.
American Smelting and Refining Co., 120 Broadway, N. Y. C.
Bridgeport Brass Co., Bridgeport 2, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Carson-Cadillac Corp., Birmingham, Ala.
The Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FLASH MIXING EQUIPMENT

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Carborundum Co., Perth Amboy, N. J.

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 3409 East 18th St., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.

FLEXIBLE JOINTS

(See Joints, Flexible Pipe.)

FLOATING COVERS (Digester)

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

FLOCCULATING EQUIPMENT

The American Well Works, Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., Inc., 3409 E. 18th St., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

FLOOR STANDS

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Merco Nordstrom Valve Co., Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

FLOW METERS

American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Fischer & Porter Co., Hatboro, Pa.
Northrop & Co., Inc., 50 Church St., New York City.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

FLOW RECORDERS

American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Fischer & Porter Co., Hatboro, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

FLOW REGULATORS

American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

FLUMES, IRON & STEEL

Armco Drainage Products Assn., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Rodney Hunt Machine Co., Orange, Mass.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

FOOT VALVE WITH STRAINER

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Edson Corp., 49 D St., So. Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Vogt Bros. Mfg. Co., 1402 W. Main St., Louisville 3, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FORMS AND FORM EQUIPMENT

Williams Form Engineering Corp., Box 925 Madison Square Station, Grand Rapids 7, Mich.

FORMS & GASKETS FOR PIPE JOINTS

Johns-Manville, 22 E. 40th St., New York City.
L. A. Weston, Adams, Mass.

FURNACES, MELTING, POURING LADLES, POTS, ETC.

Atlas Mineral Products Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.

GARBAGE DISPOSAL APPARATUS

Carborundum Co., Perth Amboy, N. J.
Chain Belt Co., Milwaukee, Wis.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Morse Boulger Destructor Co., 205 W. East 42nd St., New York, N. Y.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

GAS DIFFUSERS

The American Well Works, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2336 Wolfram St., Chicago Ill.
Dorr Co., 570 Lexington Ave., New York City.
Vogt Mfg. Co., Louisville, Ky.

GAS ENGINES

(See Engines, Gas & Gasoline)

GAS HOLDERS

Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

GAS INDICATORS AND DETECTORS

Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

GAS MASKS (All Types)

Mine Safety Appliances Co., Braddock, Thomas and Meade St., Pittsburgh, Pa.

GAS PUMPS

(See Pumps, Gas)

GAS PURIFICATION

Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.

GAS REGULATORS
(Pressure & Flow)
(See Regulators—Water & Gas)

GATES, ROLLER

Hunt, Rodney, Machine Co., Orange, Mass.

GATES, SHEAR

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

GATES, SLUICE

American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N Y.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
S. Morgan Smith Co., York, Pa.

GATE VALVE OPERATOR

Payne Dean & Co., Laconia, N. H.

GATE VALVES

(See Valves, Gate.)

GAUGES (Liquid Level, Pressure Recording)

American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City (Pressure)
Photoswitch, Inc., 21 Chestnut St., Cambridge, Mass.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Wallace & Tiernan Co., Inc., Newark, N. J.

GEARS, SPEED REDUCING

De Laval Steam Turbine Co., Trenton, N. J.
The Earle Gear & Machine Co., 4725 Stenton Ave., Philadelphia 44, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Lombard Governor Corp., Ashland, Mass.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Machy. Corp., Harrison, N. J.

GENERATOR SETS, GAS & DIESEL ENGINES

(See Engine Generating Sets)

GOOSENECKS

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

GRAVEL, FILTER

Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Tamms Silica Co., 228-WS N. La Salle St., Chicago, Ill.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Zeolite Chemical Co., 140 Cedar St., New York City.

GREEN SAND (Zeolite)

Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Zeolite Chemical Co., 140 Cedar St., New York City.

GRINDERS, SCREENINGS

Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
H. K. Porter Co., Inc., 49th and Harrison Sts., Pittsburgh, Pa.

GRIT CHAMBER EQUIPMENT

The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

GUNITING CONTRACTING

Cement Gun Co., P. O. Box 424, Allentown, Pa.

HOSE, STEAM, AIR, WATER, SUCTION

American Brass Co., Waterbury, Conn.
Bridgeport Brass Co., Bridgeport 2, Pa.
Edson Corp., 49 D St., So. Boston, Mass.
Gardner-Denver Co., Quincy, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Schramm, Inc., West Chester, Pa.
Sullivan Machinery Co., Michigan City, Indiana.

HYDRANT PUMPS

(See Pumps, Hydrant.)

HYDRANTS (Fire)

The Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.

Mueller Co., Decatur, Ill.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

HYDROGEN ION EQUIPMENT

(See pH Test Equipment.)

HYPO-CHLORINATORS

Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

HYPOCHLORITES (High Test)

(See Calcium Hypochlorite)

INCINERATORS

Dorr Co., Inc., 570 Lexington Ave., New York City.
Morse Boulger Destructor Co., 205 E. 42nd St., New York City.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

INDICATOR POSTS

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Bros. Mfg. Co., 1402 W. Main St., Louisville 3, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

INSULATION

Carborundum Co., Perth Amboy, N. J.
Ford Meter Box Co., Wabash, Ind. (Water Meter).
Johns-Manville, 22 E. 40th St., New York City.

IRON SULPHATE

Innis, Speiden & Co., 117 Liberty St., New York City.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

JOINTING COMPOUND AND MATERIALS

Atlas Mineral Prod. Co., Mertztown, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Products Corp., 6051 West 65th St., Chicago, Ill.

JOINTS, EXPANSION—PIPE

Amer. Cast Iron Pipe Co., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., N. Y., N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Lock Joint Pipe Co., Ampere, N. J.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

JOINTS, MECHANICAL, FLEXIBLE

American Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
Lock Joint Pipe Co., Ampere, N. J.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

JUTE, BRAIDED AND TWISTED

Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Johns-Manville, 22 E. 40th St., New York City.

LABORATORY APPARATUS

Carborundum Co., Perth Amboy, N. J.
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
E. Leitz, 730 Fifth Ave., New York City.
Omega Mach. Co., Inc., 3409 E. 18th, Kansas City, Mo.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

LEAK LOCATING INSTRUMENTS

(See Water Leak Locating Instruments)

LIQUID CHLORINE

(See Chlorine, Liquid.)

LIME

National Lime Assn., 927 Fifteenth St. N. W. Washington, D. C.

LUBRICATING OILS & GREASES

Macmillan Petroleum Corp., 530 W. Sixth St., Los Angeles, Calif.

MANOMETERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

MAP REPRODUCTIONS

Lithoprint Co. of N. Y., 145 Hudson St., New York City.

METER ACCESSORIES, BOXES, HOUSING, ETC.

Badger Meter Co., Milwaukee, Wis.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METER COUPLINGS & YOKES

American Meter Co., 60 E. 42nd St., New York City.
Badger Meter Mfg. Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Hays Mfg. Co., Erie, Pa.
Hersey Mfg. Co., E and 2nd Sts., South Boston 21, Mass.
Mueller Co., Decatur, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, GAS

American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Fischer & Potter Co., Hatboro, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METERS, PITOT

Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METER TESTING EQUIPMENT

American Meter Co., 60 E. 42nd St., New York City.
Badger Meter Mfg. Co., Milwaukee, Wis.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
National Meter Division of Pittsburgh Equitable Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Worthington - Gamon Meter Co., Newark, N. J.

METERS, VENTURI

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upham Sts., Philadelphia, Pa.

METERS, WATER & SEWAGE

American Meter Co., 60 E. 42nd St., New York City.
Badger Meter Mfg. Co., Milwaukee, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Hersey Mfg. Co., E and 2nd Sts., South Boston 27, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
National Meter Division of Pittsburgh Equitable Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Phoenix Meter Corp., Prince Bay, Staten Island, New York.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.
Worthington - Gamon Meter Co., Newark, N. J.

METER WASHERS

Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

MILL SUPPLIES

Tucker Co., Inc., The, 75 Murray St., New York, N. Y.

MIXERS, CHEMICAL

The American Well Works, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Lombard Governor Corp., Ashland, Mass.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
H. K. Porter Co., Inc., 49th and Harrison St., Pittsburgh, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

MIXERS, CONCRETE
(See Concrete Mixers)

MIXING EQUIPMENT
(Water & Sewage)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., 1600 W. Bruce St., Milwaukee, Wis.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40 Pa.
H. K. Porter Co., Inc., 49th and Harrison Sts., Pittsburgh, Pa.
Vogt Mfg. Co., Box 1122, Louisville 1, Ky.
Yeomans Brothers Equipment Co., 1433 Dayton St., Chicago 22, Ill.

MOTORS, ELECTRIC
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Star Electric Motor Co., Bloomfield, N. J.

NIPPLES, PIPE
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.

NO-OX-ID
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.

NOZZLES, FLOW
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

NOZZLES, SPRAY
Chain Belt Co., Milwaukee, Wis.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Mueller Brass Co., Port Huron, Mich.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

ODOR & CARBON EVALUATION AIDS
American Norit Co., Jacksonville, Fla.
Darco Corp., 60 E. 42nd St., New York City 17.
Industrial Chemical Sales Div., West Va. Pulp & Paper Co., 230 Park Ave., New York City.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Stuart Brumley Corp., Baltimore, Md.

OPERATING TABLES
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

ORIFICES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

PACKING
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hyde-ro Rings (Ralph H. Hyde), P. O. Box 1, Campbell, Calif.
Johns-Manville, 22 E. 40th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.

PACKING, RAWHIDE
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

PAINT, ACID RESISTING
Atlas Mineral Prod. Co., Mertztown, Pa.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.
Stuart Brumley Corp., Baltimore, Md.
Tamms Silico Co., 228-WS N. LaSalle St., Chicago, Ill.

PENSTOCKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Rodney Hunt Machine Co., Orange, Mass.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

pH TEST EQUIPMENT
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
E. Leitz, Inc., 730 Fifth Ave., New York City.
Beckman Instruments Div., National Technical Laboratories, So. Pasadena, Calif.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

PIPE AND TANK COATINGS
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.
Stuart Brumley Corp., Baltimore, Md.

PIPE, ASBESTOS-CEMENT
Johns-Manville Co., 22 E. 40th St., New York City.

PIPE BENDING MACHINES
Hays Mfg. Co., Erie, Pa.

PIPE, CAST IRON
American Cast Iron Pipe Co., Birmingham, Ala.
Central Foundry Co., 386 4th Ave., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hunt, Rodney, Machine Co., Orange, Mass.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, CEMENT LINED
American Cast Iron Pipe Co., Birmingham, Ala.
Cement Lined Pipe Co., 93 Brookline St., Lynn, Mass.
Central Foundry Co., 386 Fourth Ave., New York City.
Centriline Corp., 140 Cedar St., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, CEMENT LINING OF
Cement Lined Pipe Co., 93 Brookline St., Lynn, Mass.
Centriline Corp., 140 Cedar St., New York City.
Tate Pipe Linings, Inc., 47 Haverhill St., Andover, Mass.

PIPE, CONCRETE, PRESSURE
Lock Joint Pipe Co., Ampere, N. J.

PIPE, COPPER AND BRASS
American Brass Co., Waterbury, Conn.
Bridgeport Brass Co., Bridgeport 2, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.

PIPE, CORRUGATED
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.

PIPE, CULVERT
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
Central Foundry Co., 386 Fourth Ave., N. Y., N. Y.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE CUTTING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE, DRILLS, JACKS AND PUSHERS
Northrop & Co., Inc., 50 Church St., New York City.

PIPE ENAMELS, PROTECTIVE—COAL TAR
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

PIPE, FELT WRAPPING
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPE FITTINGS (See Fittings Pipe)

PIPE—GALVANIZED, LIGHT-WEIGHT
(Quick Coupling, Transportable for Conveying Water)
Armco Drainage Products Assoc., Middletown, Ohio.
Champion Corp., Hammond, Ind.

PIPE JOINT COMPOUNDS
(See Jointing Compounds.)

PIPE JOINTS (Mechanical)
Carson-Cadillac Corp., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., N. Y., N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
L. A. Weston, Adams, Mass.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE JOINT TOOLS
Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

PIPE, LEAD LINED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.

PIPE LOCATORS
Aqua Survey & Instrument Co., 1409 Marlowe Ave., Cincinnati, Ohio.
Frank N. Blake, North Adams, Mass.
S. F. Ferguson, Douglas Hotel Bldg., Newark, N. J.
Fisher Research Lab., 1961 University Ave., Palo Alto, Calif.
Northrop & Co., Inc., 50 Church St., New York City.

PIPE PUSHERS
Northrop & Co., Inc., 50 Church St., New York City.

PIPE, SEWER
American Cast Iron Pipe Co., Birmingham, Ala.
Am. Concrete Pipe Assn., 33 W. Grand Ave., Chicago, Ill. (Reinforced Concrete)
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.
A. Wyckoff & Son Co., Elmira, N. Y.

PIPE, STEEL
American Rolling Mill Co., Middletown, Ohio.
Cement Lined Pipe Co., Lynn, Mass.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, SUBAQUEOUS
American Cast Iron Pipe Co., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., N. Y., N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE TAPPING MACHINES

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE TEST PLUGS

Northrop & Co., Inc., 50 Church St., New York City.

PIPE, WELDED STEEL

American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2196 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
John Nooter Boiler Works Co., 1410 So. 2nd St. St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co. Pittsburgh, Pa.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

PIPE, WRAPPING

Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPING TOOLS

Tucker Co., Inc., The, 75 Murray St., New York, N. Y.

PITOT TUBES

Pitometer Company, 50 Church St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT

Dracco Corp., Cleveland, Ohio.

PNEUMATIC TOOLS

Schramm, Inc., Westchester, Pa.
Sullivan Mach. Co., Michigan City, Ind.

POROUS TUBES AND PLATES

Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.

PRESSURE REGULATORS

American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
The Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

PROPORTIONING EQUIPMENT (Chemical)

Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter, Hatboro, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Ave., Kansas City, Mo.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby,
Omega Machine Co., 4010 Penn Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

PUMP PRIMERS

Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Roots-Connersville Blower Corp., Connersville, Ind.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

PUMPS, ACID-HANDLING

Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton-Dowd Co., Quincy, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Lombard Governor Corp., Ashland, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Oliver United Filters, New York 18, N. Y.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, BOILER FEED

The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton-Dowd Co., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pump Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Lombard Governor Corp., Ashland, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, CELLAR DRAINER

Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dayton-Dowd Co., Quincy, Ill.
The Deming Co., Salem, Ohio.
Economy Pumps, Inc., 1024 Weller Ave., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, CENTRIFUGAL

The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton-Dowd Co., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pump Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Homelite Corp., Port Chester, N. Y.
Layne & Bowler, Inc., Memphis, Tenn.
Lombard Governor Corp., Ashland, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., 50 Church St., New York City.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, DEEP WELL

The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
The Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, DIAPHRAGM

Ralph B. Carter Co., 53 Park Place, New York City.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
The Deming Co., Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, DRAINAGE (See Pumps, Sewage and Drainage)

PUMPS, HYDRANT

Edson Corp., 49 D St., South Boston, Mass.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.

PUMPS, JETTING

Ralph B. Carter Co., 53 Park Place, New York, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.

PUMPS, PORTABLE

Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Dayton-Dowd Co., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pumps, Inc., 1024 Weller Ave., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Homelite Corp., Port Chester, N. Y.
Lombard Governor Corp., Ashland, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, ROTARY

De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SELF PRIMING

Aurora Pump Co., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton-Dowd Co., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Homelite Corp., Port Chester, N. Y.
Northrop & Co., 50 Church St., New York City.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, SEWAGE AND DRAINAGE

The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton-Dowd Co., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.

Economy Pumps, Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Lombard Governor Corp., Ashland, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
S. Morgan Smith Co., York, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, SLUDGE

The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton-Dowd Co., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Fairbanks, Morse & Co., 600 S Michigan Ave., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, SUMP

The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton-Dowd Co., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pumps Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Lombard Governor Corp., Ashland, Mass.
Michigan Ave., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, TURBINE

The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Dayton-Dowd Co., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
S. Morgan Smith Co., York, Pa.
Turbine Equip Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, VACUUM

Allen-Billmyre Corp., 449 Fayette Ave., Mamaroneck, N. Y.
Barrett, Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps Inc., Hamilton, O.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

RATE OF FLOW CONTROLLERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Fischer & Porter Co., Hatboro, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

RATE OF FLOW RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Fischer & Porter Co., Hatboro, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Northrop & Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

REAMERS

Mueller Co., Decatur, Ill.

RECARBONATORS

The American Well Works, Aurora, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

RECUPERATOR

Carborundum Co., Perth Amboy N. J.

REFRACTORIES

Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

REGULATORS, SEWAGE

Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

REGULATORS, PRESSURE

(Water and Gas)
American Meter Co., 60 E. 42nd St., New York City.
American Radiator Co., Bessemer Bldg., Pittsburgh, Pa.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia Pa.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

RESPIRATORS

Mine Safety Appliances Co., Braddock, Thomas and Meade Sts, Pittsburgh, Pa.

ROBOT FILTER AND SOFTENER OPERATORS

Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RUST PREVENTION

(Tanks, Pipe Lines, Submerged Metal)
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.
(Cathodic Protection)
Philadelphia Quartz Co., 124 S. Third St., Philadelphia, Pa.

SADDLES, PIPE

Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave. Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

SAFETY EQUIPMENT, (For Workers)

Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

SAMPLERS AND SAMPLING TABLES

Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

SAND EXPANSION INDICATORS

Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., Baltimore, Md.

SCALE PREVENTION CHEMICALS

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Permutit Co., 330 W. 42nd St., New York City.

SCALES, SLUDGE CONVEYOR

Builders-Providence, 9 Codding St., Providence, R. I.

SCALES, WEIGHING

Fairbanks-Morse Co., 600 S. Michigan Ave., Chicago 5, Ill.

SCREENS, INTAKE

Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Rodney Hunt Machine Co., Orange, Mass.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.

SCREENS, SAND, GRAVEL AND STONE

Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SEWAGE

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Rodney Hunt Machine Co., Orange, Mass.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphai 40, Pa.

SCREENS, WATER WELL

Layne & Bowler, Inc., Memphis, Tenn.

SERVICE BOXES

Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 So. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
United Concrete Form Products Co., 5243 W. 25th Pl., Chicago, Ill.

SEWAGE EJECTORS

Ralph B. Carter Co., 53 Park Pl., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps, Inc., 1024 Weller Ave., Hamilton, Ohio.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

SEWAGE SAMPLERS

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

SEWAGE SCREENING GRINDERS

(See Grinders, Screenings)

SEWAGE SLUDGE INCINERATOR

Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Morse Boulger Destructor Co., 216 East 45th St., New York City.
Nichols Engineering & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

SEWER CLEANERS

Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
W. H. Stewart, P. O. Box 767, Syracuse, N Y.

SEWER PIPE

(See Pipe, Sewer)

SEWER PIPE JOINTS

Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
L. A. Weston, Adams, Mass.

SEWER PIPE LOCATORS

Frank N. Blake, North Adams, Mass.

SEWER RODS

Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N Y.

SHEETING

American Brass Co., Waterbury, Conn.
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.
Bridgeport Brass Co., Bridgeport 2, Conn.

SIGHT FEEDERS (For Chemical Pumps)

Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

SIPHONS (Sewage)

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City. (Alternating.)
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

SLEEVES, PIPE REPAIR

Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

SLEEVES, TAPPING (Valve)

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.

SLUDGE COLLECTORS

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pemutit Co., 330 W. 42nd St., New York City.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

SLUDGE DISINTEGRATORS

Gruendler Crusher & Pulverizer Co., 2913 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE ELEVATORS, LIQUID

Chain Belt Co., Milwaukee, Wis.

SLUDGE GAS ENGINES

(See Engines, Sludge Gas)

SLUDGE PUMPS

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Dorr Co., 570 Lexington Ave., New York City.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

SODA ASH

Diamond Alkali Co., Pittsburgh, Pa
Hood Chemical Co., 450 W. 31st St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt. Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Div., Grant Bldg., Pittsburgh 19, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.
Solvay Sales Corp., 40 Rector St., New York City.

SODIUM ALUMINATE

Dearborn Chemical Co., 310 Michigan Ave., Chicago, Ill.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.

SODIUM CHLORITE

Mathieson Alkali Works, 60 E. 42nd St., New York 17, N. Y.

SODIUM PHOSPHATES (Glassy)

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.

SODIUM SILICATE

Diamond Alkali Co., Pittsburgh, Pa.
General Chemical Co., 40 Rector St., New York City.
Philadelphia Quartz Co., 124 S. Third St., Philadelphia 6, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Standard Silicate Division, Diamond Alkali Co., Pittsburgh, Pa.

SOFTENERS

(See Water Softening Equipment)

SPEED REDUCERS, TRANSMISSION

De Laval Steam Turbine Co., Trenton, N. J.
The Earle Gear & Machine Co., 4725 Stenton Ave., Philadelphia 44, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Lombard Governor Corp., Ashland, Mass.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

SPRINKLING FILTERS (Sewage)

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SPRINKLING FILTER UNDERDRAINS

(See Filter Underdrains, Sewage)

STACKS

Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STACKS, FUME

Johns-Manville, 22 E. 40th St., New York City.

STANDPIPE AND TANKS

Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
H. K. Porter Co., 49th & Harrison, Pittsburgh, Pa.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

STANDPIPE AND TANK PRESERVATION

(See Cathodic Protection Process.)

STERILIZING WATER MAINS

(See Water Main Sterilization)

STIRRERS (Laboratory)

Dorr Co., 570 Lexington Ave., New York City.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Phipps & Bird, Inc., Sixth & Byrd Sts., Richmond, Va.
H. K. Porter Co., Inc., 49th and Harrison Sts., Pittsburgh, Pa.
Stuart Brumley Corp., Baltimore, Md.

STOKERS

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.

STORAGE TANKS (See Standpipes and Tanks)

STRAINERS, SUCTION

Barrett, Haentjens & Co., Hazleton, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., South Boston, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

SULPHATE OF ALUMINA

(See Filter Alum)

SULPHUR DIOXIDE (Liquid)

Great Western Div., Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Virginia Smelting Co., West Norfolk, Va.

SUPER-CHLORINATION UNITS (See Chlorinators)

SWIMMING POOL EQUIPMENT

Ralph B. Carter Co., 53 Park Place, New York City.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

SWITCHBOARDS

Climax Engineering Co., Clinton, Iowa.
Johns-Manville, 22 E. 40th St., New York, N. Y.

TANKS, ELEVATED STEEL (See Standpipes and Tanks)

TANKS, PLASTIC

Proportioneers, 9 Codding St., Providence 1, R. I.

TANKS, RUBBER LINED

Atlas Mineral Products Co., Mertztown, Pa.
Dorr Co., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo. Newark 1, N. J.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

TANKS, STEEL

(See Standpipes and Tanks)

TAPPING MACHINES

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

TASTE & ODOR REMOVAL CHEMICALS

Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Norit Co., Jacksonville Fla.
Cliffs Dow Chemical Co., Marquette, Mich.
Darco Corp., 60 E. 42nd St., New York City 17.
Graver Tank & Mfg. Co., East Chicago, Ill.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York City 17.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Stuart Brumley Corp., Baltimore, Md.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

TESTERS (Water Meter)

Ford Meter Box Co., Wabash, Ind.
Hersey Mfg. Co., E and 2nd Sts., South Boston 27, Mass.
Mueller Co., Decatur, Ill.

National Meter Division of Pittsburgh Equitable Meter Co., 4221 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Worthington-Gamon Meter Co., Newark, N. J.

THICKENERS

Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

TOOLS, PNEUMATIC

Schramm, Inc., Westchester, Pa.
Sullivan Machinery Co., Michigan City, Ind.

TRAPS, DRIP, FLAME, SEDIMENT

Pacific Flush Tank Co., 4341 Ravenswood Ave., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

TRICKLING FILTER UNDERDRAINS

(See Filter Underdrains.)

TRICKLING FILTERS (High Rate, High Capacity)

The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Co., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

TRITURATORS

(See also Grinders)
Chain Belt Co., Milwaukee, Wis.

TUNNEL LINER PLATES

American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Prod. Assn., Middletown, Ohio.

TUNNEL MACHINERY, BORING & LINING

Jeffrey Mfg. Co., Columbus, Ohio.

TURBINES, HYDRAULIC

De Laval Steam Turbine Co., Trenton, N. J.
Hunt, Rodney, Machine Co., Orange, Mass.
Morris Machine Works, Baldwinsville, N. Y.
S. Morgan Smith Co., York, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

TURBINES, STEAM

De Laval Steam Turbine Co., Trenton, N. J.
Morris Machine Works, Baldwinsville, N. Y.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

VALVE BOXES

Central Foundry Co., 386 Fourth Ave, New York City.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Ford Meter Box Co., Wabash, Ind.
Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVE BOX LOCATORS

S. F. Ferguson, 11 Hill St., Newark, N. J.
Northrop & Co., Inc., 50 Church St., New York City.

VALVE OPERATOR

(See Gate Valve Operator)

VALVES

American Rolling Mill Co., Middletown, Ohio.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Armco Drainage Products Assn., Middletown, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Rodney Hunt Machine Co., Orange, Mass.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Lombard Governor Corp., Ashland, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Vogt Bros. Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, AIR RELEASE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, AIR & VACUUM

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Chicago, Ill.

VALVES, ALTITUDE

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 So. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, BUTTERFLY

Hunt, Rodney, Machine Co., Orange, Mass.

VALVES, CHECK

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Barrett, Haentjens & Co., Hazleton, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
R. D. Wood Co., Philadelphia, Pa.

VALVES, CHLORINE

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

VALVES, CONE,

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, EMERGENCY TRIP

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ross Valve Mfg. Co., Troy, N. Y.

VALVES, FLAP

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FLOAT

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co. 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, FOOT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Edson Corp., 40 D St., South Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FOUR WAY

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, GATE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, HYDRAULIC CYLINDER OPERATED

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.

Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MOTOR OPERATED

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MUD AND PLUG

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Brothers Mfg. Co., Louisville, Ky.

VALVES, PRESSURE REDUCING

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith, York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

VALVES, RELIEF

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hays Mfg. Co., Erie, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Lombard Governor Corp., Ashland, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Decatur, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

VALVES, RUBBER, GLASS AND LEAD LINED

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
S. Morgan Smith, York, Pa.
Johns-Manville, 22 E. 40th St., New York, N. Y.

VALVES, SPECIAL AUTOMATIC

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Barrett, Haentjens & Co., Hazleton, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, WATER METER SPECIAL

Ford Meter Box Co., Wabash, Ind.

VARIABLE SPEED TRANSMISSIONS

The Earle Gear & Machine Co., 4725 Stenton Ave., Philadelphia 44, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Lombard Governor Corp., Ashland, Mass.
Omega Machine Co., 3409 E. 18th, Kansas City, Mo.

VENTURI TUBES

Bailey Meter Co., 1072 Ivanhoe, Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

VIBRATORS, ELECTRO-MAGNETIC

Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

WASTE GAS BURNERS

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

WATER ANALYSIS EQUIPMENT AND REAGENTS

Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
E. Leitz, 730 Fifth Ave., N. Y., N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

WATER HAMMER ARRESTERS

Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
S. Morgan Smith Co., York, Pa.

WATER MAIN STERILIZATION (A Service)

Luther & Wood, 310 Chandler Bldg., 1427 Eye St., N. W., Washington, D. C.

WATER LEAK, LOCATING INSTRUMENTS

S. F. Ferguson, 11 Hill St., Newark 2, N. J.
Fisher Research Lab., 1961-63-65 University Ave., Palo Alto, Calif.
Northrop & Co., Inc., 50 Church St., New York City.
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

WATER LEVEL RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

WATER MAIN CLEANING

National Water Main Cleaning Co., 30 Church St., New York City.
Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
Stuart Brumley Corp., Baltimore, Md.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS

General Paint Corp., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Modern Waterproofing Paint Co., 1270 Sixth Ave., New York City.
Reilly Tar & Chem. Corp., Merchants Bank Bldg., Indianapolis.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.
Stuart Brumley Corp., Baltimore, Md.

WATER SOFTENING CHEMICALS AND COMPOUNDS

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Mathieson Alkali Works, 60 East 42nd St., New York City.
Permutit Co., 330 W. 42nd St. New York City.
Pittsburgh Plate Glass Co. Columbia Chemical Div., Grant Bldg., Pittsburgh 19, Pa.
Stuart Brumley Corp., Baltimore, Md.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.
Zeolite Chemical Co., 140 Cedar St., New York City.

WATER SOFTENING EQUIPMENT

The American Well Works, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., 1600 W. Bruce St., Milwaukee, Wis.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Link Belt Co., 2045 S. Hunting Park Ave., Philadelphia, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Nooter, John, Boiler Works Co., 1410 2nd St., St. Louis 4, Mo.
Omega Machine Co., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., Baltimore, Md.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York City.

WATER STABILIZATION

The American Well Works, Aurora, Ill.
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.
Zeolite Chemical Co., 140 Cedar St., New York, N. Y.

WATER SUPPLY CONTRACTORS

Ambursen Eng. Corp., 295 Madison Ave., New York, N. Y.
Layne & Bowler,& Inc., Memphis, Tenn.

WATER TREATMENT FOR SCALE AND CORROSION

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
The Permutit Co., 330 West 42nd St., New York City.
Stuart Brumley Corp., Baltimore, Md.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

WATER WASTE SURVEYS

S. F. Ferguson, 11 Hill St., Newark 2, N. J.
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co. 68th & Upland Sts., Philadelphia, Pa.

WEATHERPROOF PAINTS, ROOF COATINGS

General Paint Corp., 3091 Mayfield Road, Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis.

WELLS, COMPLETE

Layne-Bowler, Inc., Memphis, Tenn.

WRAPPING, PIPE
(See Pipe, Wrapping)

WRENCHES, REVERSIBLE RATCHET

Dresser Mfg. Co., Bradford, Pa.

ZEOLITE AND ZEOLITE SOFTENERS

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York City.

INFORMATION ON WATER AND SEWAGE WORKS PROBLEMS

(WHERE TO FIND IT)

By LINN H. ENSLOW
Editor, "Water Works and Sewerage"

IT goes without saying that information required by water works men and sewage works operators is not concentrated in two or three books. The nearest approach to concentrated information for water works men is found in the manuals published by the American Water Works Association — "Water Works Practice," the "Purification Manual" and the "Accounting Manual."

Text books, manuals, hand-books, journals, and catalogs are named alphabetically in the attached list of recommended reference works for water and sewage works men.

The list represents the majority opinions of operating men, managers, engineers and chemists called on to offer suggestions in making up a set of reference works. It is an attempt to recommend those books of greatest usefulness.

LIST NO. 1—FOR WATER WORKS MANAGERS AND OPERATORS

[For Small and Moderate Size Systems.]

Books	*Publishers*	*Authors*
A. B. C. of Hydrogen Ion Control (F)	LaMotte Company, Baltimore, Md.	
American Civil Engineering Handbook—5th Ed. ($8.00)	John Wiley & Sons, New York City	Merriman & Wiggin
Bul. No. 21 (a Handbook on Hydraulics) (F)	National Tube Co., Pittsburgh, Pa.	
Conversion Factors for Engineers (F)	The Door Co., New York City	
Copper Sulphate in Control of Micro Organisms (F)	Phelps Dodge Refining Corp., New York City	Hale
Elements of Water Supply Engineering (2nd Ed.)	John Wiley & Sons, New York City	Waterman
Engineering Data in Flow of Fluids in Pipes (F)	Crane Co., Chicago	
Examination of Water—6th Ed. ($3.00)	John Wiley & Sons, New York City	Mason & Buswell
Fire Engine Tests and Fire Stream Tables (F)	National Board of Fire Underwriters, N. Y. C.	
Handbook of Cast Iron Pipe (F)	Cast Iron Pipe Research Assn., Chicago	
Handbook of Fire Protection ($4.50)	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Hydraulic Tables—3rd Ed. ($2.00)	John Wiley & Sons, New York City	Williams & Hazen
Lab. Manual—Chemical & Bacterial Analysis Water and Sewage, 3rd Edition ($3.00)	McGraw Hill Co., New York City	Theroux, Eldridge, Mallman
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa.	Various
Manual for Water Works Operators ($3.00)	Texas Water Works & Sewerage Short School, Austin, Tex.	Various
Manual of Water Quality and Treatment	Am. Water Works Assn., New York City	Various
Manual of Water Works Accounting	Am. Water Works Assn., New York City	Various
Microscopy of Drinking Water (4th Ed. $7.00)	John Wiley & Sons, New York City	Whipple-Fair
Modern pH Control (F)	W. A. Taylor Co., Baltimore, Md.	
Plane Surveying ($3.50)	John Wiley & Sons, New York City	Tracy
Plumber's Handbook ($4.00)	McGraw-Hill Co., New York City	Dibble
Public Water Supplies—4th Ed. ($6.00)	John Wiley & Sons, New York City	Turneaure & Russell
Standard Methods of Water Analysis, 8th Ed. ($2.50)	A. P. H. A. and A. W. W. A., New York City	Various
Technical Bulletin on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J.	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C.	
Treatment of Municipal and Industrial Waters—Tech. Bul. No. 8 (F)	The Solvay Process Co., New York City	
Water Purification ($7.00)	McGraw Hill Co., New York City	Ellms
Water Purification Control, 2nd Edition ($1.75)	Williams & Wilkins, Baltimore, Md.	Hopkins
Water Purification for Plant Operators ($2.50)	McGraw Hill Co., New York City	Norcom and Brown
Water Rate Structures in America (F)	Public Service Commission of Wisconsin, Madison, Wis.	
Water Supply Control (nominal charge)	N. Y. State Dept. Health, Albany, N. Y.	
Water Treatment and Purification ($2.50)	McGraw Hill Co., New York City	Ryan
Water Works Engineering in Disaster (F)	O.C.D. Pub. No. 2022, Washington, D. C.	McCallum
Water Works Handbook ($7.00)	McGraw Hill Co., New York City	Flynn, Weston & Bogert
Water Supply & Treatment, 3rd Ed. ($0.75)	National Lime Assn., Washington, D. C.	Hoover

(F) Available as Free Publication at this writing.

Journals and Magazines (Applies to Lists 1 and 2)

Journal and Monographs of the American Waterworks Association
Journal of the New England Water Works Association
Current Water Works Technical Magazines and Trade Papers

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS
(In addition to List No. 1)

Books	*Publishers*	*Authors*
Boiler Feedwater Purification ($4.00)	McGraw-Hill Co., New York City	Powell
Business Administration for Engineers ($5.00)	McGraw-Hill Co., New York City	Harding & Canfield
Business Law for Engineers ($4.00)	McGraw-Hill Co., New York City	Allen
Chemistry of Water and Sewage Treatment****	Chemical Catalog Company, New York City****	Buswell
Concrete Engineers' Handbook ($6.00)	McGraw-Hill Co., New York City	Hool & Johnson
Corrosion; Causes and Prevention ($7.00)	McGraw-Hill Co., New York City	Speller
Design of Dams ($5.00)	McGraw-Hill Book Co., New York City	Hanna and Kennedy
Elements of Hydraulics ($1.50)	John Wiley & Sons, New York City	Merriman
Elements of Water Bacteriology—5th Ed. ($2.50)	John Wiley & Sons, New York City	Prescott & Winslow
Elimination of Tastes and Odors in Water ($5.00)	McGraw-Hill Co., New York City	Baylis
Fresh Water Biology ($7.00)	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae ($6.00)	McGraw-Hill Co., New York City	Smith
Ground Water ($6.00)	McGraw-Hill Book Co., New York City	C. F. Tolman
Guiding Principles of Public Service Regulations (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Handbook of Applied Hydraulics	McGraw-Hill Co., New York City	Various
Handbook of Hydraulics ($4.00)	McGraw-Hill Co., New York City	King
Hydraulic Measurements	John Wiley & Sons, Inc.	Addison
Index to Jour. of A. W. W. A.—1881-1933 ($2.00)	Am. Water Wks. Assn., New York City	
"Industrial Water Supplies" (nominal charge)	Ohio Geological Survey, Columbus, Ohio	C. W. Foulk
Mechanical Engineers' Handbook—11th Ed. ($5.00)	John Wiley & Sons, New York City	Kent
pH and Its Practical Application ($3.50)	Williams & Wilkins Co., Baltimore, Md.	LaMotte, Kenny & Reed
Plumbing Engineering ($3.50)	Pittman Publishing Co., New York	Cleverdon
Pocket Companion (nominal)	Carnegie-Steel Corp., New York City	
Public Utility Rates****	McGraw-Hill Co., New York City****	Barker
Public Utility Rate Structures ($4.00)	McGraw-Hill Co., New York City	Nash
Summary of Census Data on Water Treatment Plants in the United States	Am. Water Works Assn. Reprint	U. S. Pub. Health Service
Textbook of Bacteriology ($8.00)	D. Appleton & Co., New York City	Zinser & Jones
The Hardy Cross Method of Distribution System Design.	Univ. of Illinois Engr. Exp. Sta. Bul. No. 286	Hardy Cross
Theory and Practice of Public Utility Valuation****	McGraw-Hill Co., New York City****	Maltbie
Water Borne Typhoid Fever Outbreaks (nominal)	Am. Public Health Bureau	Wolman & Gorman
Water Supply and Sewerage ($5.00)	McGraw-Hill Co., New York City	Steel
Water Supply Engineering (3rd Ed. $6.00)	McGraw-Hill Co., New York City	Babbitt & Doland
Water Supply Paper No. 658 (Quality of Waters) (nominal)	U. S. Geological Survey, Washington, D. C.	Stabler

****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.
For Journals see list No. 1.

LIST NO. 3—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS**

Books	*Publishers*	*Authors*
Chemical Treatment of Sewage (nominal)	Amer. Pub. Health Assn., N. Y. C.	Committee Report
Chlorination in Sewage Treatment****	Amer. Pub. Health Assn., N. Y. C.	Committee Reports
Laboratory Manual of Water and Sewage Analysis 3rd Ed. ($3.00)	McGraw-Hill Co., New York City	Theroux, Eldridge & Mallman
Manual of Sewage Works Operation****	New Jersey Sewage Expt. Sta., New Brunswick, N. J.****	
Operation and Control of Sewage Treatment Plants	New York State Dept. Health	N. Y. State Dept. Health
Principles of Sewage Treatment ($0.50)	National Lime Assn., Washington, D. C.	W. Rudolfs and Staff
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tiernan Co., Newark, N. J.	Various
Sewage Treatment ($3.00)	John Wiley & Sons, Inc., New York City	Imhoff and Fair
Sewage Treatment Works ($6.00)	McGraw-Hill Book Co., New York City	Keefer
Sewerage and Sewage Disposal Text Book ($6.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Sewer Rentals ($1.50)	Am. Public Works Assn., Chicago	Various
Standard Methods of Water and Sewage Analysis ($2.50)	Amer. Pub. Health Assn., N. Y. C.	A. W. W. A.-A. P. H. A.

Journals and Magazines

Sewage Works Journal—(Official publication, Sewage Works Federation)
Current Sewerage Magazines

LIST NO. 4—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS**
(In addition to List No. 3)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment (1935 Edition) ($7.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Industrial Waste Treatment Practice ($5.00)	McGraw-Hill Co., New York City	Eldridge
Modern Sewage Disposal ($3.50)	Federation of Sewage Works Assns., New York City	Various
Sewage Disposal****	John Wiley and Sons, New York City****	Kinnicutt, Winslow & Pratt
Sewerage, 11th Ed. ($4.50)	John Wiley & Sons, New York City	Folwell
Sewerage and Sewage Treatment—2nd Ed. ($4.00)	Intl. Text Book Co., Scranton, Pa.	Hardenberg
Sewerage and Sewage Treatment—4th Ed. ($5.00)	John Wiley & Sons, New York City	Babbitt
Sewers (25 shillings)	Chapman & Hall, London	Bevan and Rees
Solving Sewage Problems ($6.00)	McGraw-Hill Co., New York City	Fuller & McClintock
The Chemistry of Water and Sewage Treatment****	Chemical Catalog Co., New York****	Buswell
The Hoover Plumbing Code (B. H. 13) (nominal)	U. S. Bureau of Standards	

(F) Available as Free Publication at this writing.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.
***Note*—Sewerage men should examine Lists 1 and 2—also for several (F) publications of value to all alike—for instance, "Conversion Factors for Engineers" and the hand-books of pipe and pump data.

WATER

FLOW, FRICTION, MEASUREMENT AND POWER

The rate of flow or the volume of water passing a cross section of a stream in a unit time is called the "discharge." If a uniform velocity at all points in the cross section of a stream were possible, there would be passing any cross section of the stream, every unit of time, a prism of water having a base equal to the cross-sectional area of the stream and a length equal to the velocity. However, due to the varying effects of friction and viscosity, the different filaments of water move with different velocities. For this reason it is common in hydraulics to deal with "mean velocities."

The discharge may be expressed in terms of the mean velocity:

$$Q = av$$

where Q = Discharge in cubic feet per second.
a = Cross-sectional area of stream in square feet.
v = Mean velocity in feet per second.

When the discharge is constant (i.e., when the same quantity of water passes any cross section of a stream during equal successive intervals of time) the flow is said to be "steady."

Flow is said to be "uniform" when there is little or no change in the cross section or velocity from point to point in a stream. Thus uniform flow implies similarity of conditions at successive cross sections at any given instant, while steady flow involves permanency of conditions at any particular cross section.

In hydraulics the term "pressure head," "static head" or simply "head" is used to designate the vertical height of a static column of liquid which, due to its weight, would produce a pressure equivalent to the pressure in the fluid at the point in question.

The "velocity head" is the height through which a body must fall in a vacuum to acquire the velocity with which water flows in a stream. The velocity head corresponding to any velocity is equal to the static head, which (neglecting friction) could cause (or could be caused by) that velocity. The relation between velocity head and velocity may be expressed by the formula:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Flow of Water Through Orifices and Tubes

As commonly used in hydraulics, the term orifice is used to designate an opening with a closed perimeter, and of regular shape, through which water flows. If the perimeter is not closed, or if the opening flows only partially full, the orifice becomes a weir.

An orifice with prolonged sides, such as a short piece of pipe two or three diameters in length, set in the side of a reservoir, is called a tube. An orifice in a thick wall has the hydraulic properties of a tube.

The theoretical velocity of a stream or jet of water issuing from an orifice is given by the formula:

$$v_t = \sqrt{2gh}$$

where v_t = Theoretical velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.
h = Head on the center of the orifice in feet.

The actual velocity of the jet is less than the theoretical velocity because of the frictional loss which occurs as the water approaches the orifice. The ratio of the actual mean velocity, v, to the theoretical velocity, v_t, is called the "velocity coefficient" and is designated by the symbol C_v. The actual mean velocity of the jet is therefore:

$$v = C_v\sqrt{2gh}$$

The stream or jet issuing from an orifice is not in all cases the same size as the opening of the orifice because of contraction effects in certain cases and flaring effects in other cases. The "contraction coefficient," C_c, of an orifice is the ratio of the cross-sectional area of the jet to that of the orifice.

The discharge from an orifice is given by the formula:

$$Q = C_vC_ca\sqrt{2gh}$$

where Q = Discharge in cubic feet per second.
a = Area of orifice opening in square feet.

It is customary to combine the coefficients C_v and C_c into a single coefficient C_d which is called a "discharge coefficient." The discharge coefficient is therefore a product of the velocity coefficient and the contraction coefficient, or $C_d = C_v \times C_c$.

The formula for discharge from an orifice then becomes:

$$Q = C_da\sqrt{2gh}$$

Table 12 gives average values of discharge coefficients for various types of orifices and tubes.

Flow of Water in Pipe and Open Channels

As the term is used in hydraulics, a pipe may be defined as a closed conduit which flows full under pressure. By open channel is meant any kind of water course with the top surface of the flowing water exposed to the atmosphere, such as a canal, aqueduct, flume, sewer or river.

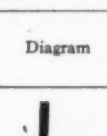
The "wetted perimeter" of any conduit is that portion of the perimeter of the cross section of the conduit in contact with the liquid.

The "hydraulic radius" of a conduit is the cross-sectional area of the stream, divided by the wetted perimeter of that section. For a circular pipe flowing either full or half full the hydraulic radius is one-fourth the pipe diameter (or one-half the pipe radius).

If a tube is tapped into the wall of a vessel or pipe containing water under pressure, the water will rise in the tube to a height equal to the head producing the pressure at the point where the tube is inserted. Such a tube is called a "piezometer" tube. Piezometer tubes measure pressure above atmospheric pressure (gage pressure) since the water surface in the tube is subjected to atmospheric pressure. When piezometer tubes are used to measure pressure heads in pipes where water is in mo-

Table 12

Discharge Coefficients for Various Types of Orifices and Tubes

Diagram	Description	Average discharge coefficient, C_d
	**SHARP-EDGED ORIFICE** The stream is contracted to about 0.62 of the area of the opening.	0.61
	ORIFICE WITH WELL-ROUNDED ENTRY There is little or no contraction and the stream is about the same size as the opening.	0.98
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When flowing full. When the length of the tube is 2½ diameters it is called a "standard short tube".	0.82
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When the stream springs clear from the tube at the upstream corner the flow is the same as for a sharp-edged orifice.	0.61
	RE-ENTRANT TUBE Length about 2½ diameters. Flowing full.	0.73
	RE-ENTRANT TUBE When the length is about one diameter it is called "Borda's Mouthpiece". Stream springs clear of the walls of the tube.	0.52

*The material under this heading has been drawn from National Tube Company's Technical Bulletin No. 21.

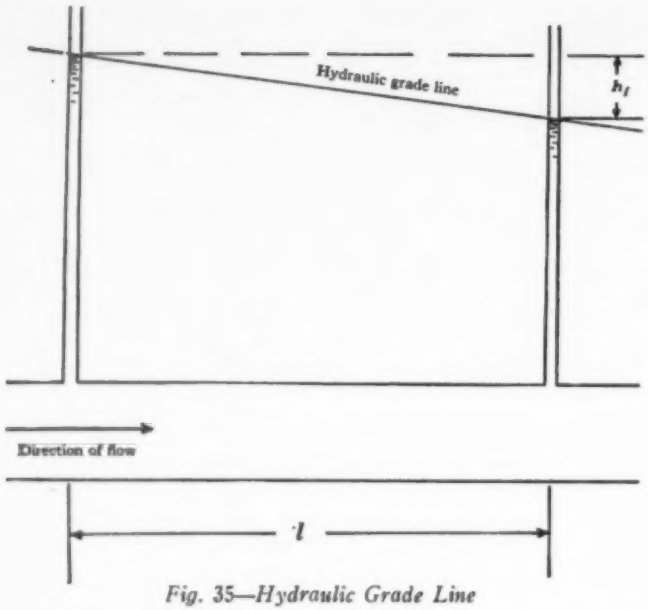


Fig. 35—Hydraulic Grade Line

tion, the end of the tube should enter the pipe at right angles to the direction of flow and the end of the tube should be flush with the inner surface of the pipe.

If a pipe full of water is provided with several piezometer tubes, a line joining the tops of the columns of water in the tubes is called the "hydraulic grade line," and the slope of this line is the "hydraulic slope" or simply the "slope." Two piezometer tubes attached to a pipe line are shown in Fig. 35. The line joining the tops of the columns of water in the tubes represents the hydraulic grade line and h_f represents the loss of head in length l. The hydraulic slope, s, is therefore:

$$s = \frac{h_f}{l}.$$

Friction

There is always friction between moving water and the surface with which the water comes into contact. There is also friction between the moving particles of the water themselves which is commonly called viscosity.

Water particles in contact with the conduit surface are retarded by friction, and viscosity causes a retardation of the particles removed from the conduit surface. Therefore, water flowing in a pipe has its maximum velocity at the center and its minimum velocity near the pipe walls.

If there were no friction losses, the theoretical velocity, v_t, at which water would discharge from a pipe or channel would be $v_t = \sqrt{2gh}$. In any long pipe or channel, however, the greater portion of the total head is used in overcoming friction.

The amount of frictional resistance offered by any surface increases with the degree of roughness of the surface. The resistance due to viscosity decreases as the temperature of the water increases.

The loss of head due to the combined effects of viscosity and friction between the moving water and the surface of the conduit is usually referred to as the loss of head due to friction.

The influences of friction and viscosity on the flow of water have been determined experimentally by various authorities and a variety of formulas for the loss of head due to friction have been derived. Only a few of the best-known and most generally used formulas will be presented in this article.

In addition to the loss of head due to friction, other losses of head result from changing the velocity or direction of flow. These special losses are considered in Table 21.

Formulas for Flow of Water In Pipe and Open Channels

The Chezy Formula

The most generally used formula for determining the velocity of flow of water in pipe and open channels is the Chezy Formula:

$$v = c\sqrt{rs}, \text{ or } v = cr^{0.5}s^{0.5}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = A coefficient which Chezy considered to be constant, but which is now known to vary with the hydraulic slope and hydraulic radius as well as with the degree of roughness of the surface with which the water comes in contact.

This formula, although originally designed for open channels, is with proper modification applicable to either open channels or pipe.

The Hazen-Williams Formula

For the same degree of roughness, the value of c for the Chezy Formula increases with the hydraulic slope and with the hydraulic radius. This is due to the fact that the exponents used for the terms in the formula are less than the true values. If the exponents were increased to correspond more nearly with the facts, the variation in the value of c would become smaller.

The Hazen-Williams Formula was designed with a view of obtaining a minimum variation in the value of c for all conduits of the same degree of roughness. That is, the object was to select values for the exponents such that c would be, as nearly as practicable, a function of the degree of roughness of the conduit surface and not of the hydraulic radius and slope.

The Hazen-Williams Formula is:

$$v = cr^{0.63}s^{0.54}0.001^{-0.04}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = Hazen-Williams coefficient of roughness.

The last term ($0.001^{-0.04}$) is a constant, and was introduced simply to equalize the value of c with the value in the Chezy Formula and other exponential formulas which may be used as a slope of 0.001 instead of at a slope of 1. Since $0.001^{-0.04}$ equals 1.318, the Hazen-Williams Formula may be written:

$$v = 1.318cr^{0.63}s^{0.54}$$

Values of Coefficient "C"

The following values of the coefficient c may be used in the Hazen-Williams Formula for computing the loss of head due to friction in new well-laid pipe:

Kind of Pipe	Coefficient c	Kind of Pipe	Coefficient c
National Duroline	148*†	Wood Stave	120
Wrought Steel	140	Riveted Steel	110
Small Brass and Copper	130	Vitrified Pipe	110
Cast Iron	130	Brick Sewers	100
Concrete	120		

*"Duroline" pipe is protected against internal corrosion and mounting friction losses by a cement base composition lining of a highly durable nature.—Ed.

†Approximately the same for cement lined pipe.—Ed.

It must be understood that these values depend upon the smoothness and regularity of the surfaces and are likely to vary in individual cases. In designing a pipe line it is customary to use somewhat lower coefficients than those above, to allow for variations due to local conditions, and for reduction of carrying capacity with age due to roughening of the inside surface, accumultaion of corrosion products, and tuberculation. However, in case of Duroline Pipe, the volume of flow remains practically unchanged over long periods of service due to the fact that rust tubercles do not form and the initially smooth inside surface is retained.

Tables 15 and 16 have been prepared to furnish directly the loss of head (h_f) in feet per 1000 feet of pipe of various sizes for different velocities and values of the coefficient c. Similar data for Duroline Pipe, based on a value of $c = 148$, is given in Table 17. These tables were calculated for actual internal diameters by the following arrangement of the Hazen-Williams Formula:

$$h_f = 1000\sqrt[0.54]{\frac{v}{1.318\,cr^{0.63}}}$$

where h_f = Loss of head in feet due to friction per 1000 feet of pipe = $1000s$.

The loss of head (h_f) for any value of the coefficient c not given in Tables 15 and 16 may be determined by multiplying the loss of head (h_f) for $c = 100$ by the factor $\sqrt[0.54]{\frac{100}{c}}$

Values of this factor corresponding to various values of the coefficient c are given below:

Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$	Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$
60	2.575	110	0.8332
70	1.936	120	.7125
80	1.512	130	.6153
90	1.215	140	.5363
100	1.000		

Table 15
Loss of Head in Pipe by Friction for National A.P.I. Line Pipe, Calculated by Hazen-Williams Formula

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=120$	$c=100$	$c=80$
1	1.049	3	4,320	1.114	6.72	8.94	12.5	18.9
		4	5,760	1.485	11.4	15.2	21.4	32.3
		5	7,200	1.856	17.3	23.0	32.3	48.8
		6	8,640	2.227	24.3	32.3	45.2	68.4
		8	11,520	2.970	41.3	55.0	77.1	117.
		10	14,400	3.712	62.5	83.1	117.	176.
		12	17,280	4.455	87.6	117.	163.	247.
		16	23,040	5.940	149.	198.	278.	421.
		20	28,800	7.425	226.	300.	421.	636.
		25	36,000	9.281	341.	454.	636.	961.
		30	43,200	11.137	478.	636.	891.	1347.
		35	50,400	12.993	636.	846.	1185.	1792.
		40	57,600	14.849	814.	1083.	1518.	2295.
1¼	1.380	4	5,760	0.858	3.01	4.01	5.61	8.49
		5	7,200	1.073	4.55	6.06	8.49	12.8
		6	8,640	1.287	6.38	8.49	11.9	18.0
		8	11,520	1.716	10.9	14.5	20.3	30.6
		10	14,400	2.145	16.4	21.9	30.6	46.3
		12	17,280	2.574	23.0	30.6	42.9	64.9
		16	23,040	3.432	39.2	52.2	73.2	111.
		20	28,800	4.290	59.3	78.9	111.	167.
		30	43,200	6.435	126.	167.	234.	354.
		40	57,600	8.580	214.	285.	399.	603.
		60	86,400	12.870	454.	603.	846.	1279.
		80	115,200	17.160	773.	1028.	1441.	2178.
1½	1.610	4	5,760	0.630	1.42	1.89	2.65	4.01
		5	7,200	.788	2.15	2.80	4.00	6.06
		6	8,640	.946	3.01	4.01	5.62	8.49
		8	11,520	1.261	5.13	6.82	9.57	14.5
		10	14,400	1.576	7.76	10.3	14.5	21.9
		12	17,280	1.891	10.9	14.5	20.3	30.6
		16	23,040	2.521	18.5	24.6	34.5	52.2
		20	28,800	3.152	28.0	37.2	52.2	78.9
		30	43,200	4.728	59.3	78.9	111.	167.
		50	72,000	7.880	153.	203.	285.	431.
		75	108,000	11.820	324.	431.	603.	912.
		100	144,000	15.759	551	734.	1028.	1554.
		125	180,000	19.699	833.	1109.	1554.	2350.
2	2.067	6	8,640	0.574	0.892	1.19	1.66	2.51
		8	11,520	765	1.52	2.02	2.83	4.28
		10	14,400	956	2.30	3.06	4.28	6.47
		12	17,280	1 147	3.22	4.28	6.00	9.07
		16	23,040	1 530	5.48	7.30	10.2	15.5
		20	28,800	1 912	8.29	11.3	15.5	23.3
		30	43,200	2.868	17.6	23.4	32.8	49.5
		50	72,000	4.781	45.2	60.2	84.3	128.
		75	108,000	7.171	95.8	128.	179.	270.
		100	144,000	9.561	163.	217.	304.	460.
		150	216,000	14.342	346.	460.	645.	975.
		200	288,000	19.122	589.	784.	1099.	1661.

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
2½	2.469	8	11,520	0.536	0.639	0.733	0.851	1.19
		10	14,400	.670	.966	1.11	1.29	1.80
		12	17,280	.804	1.35	1.55	1.80	2.53
		16	23,040	1.072	2.31	2.65	3.07	4.30
		20	28,800	1.340	3.49	4.00	4.64	6.51
		25	36,000	1 675	5.27	6.05	7.02	9.83
		50	72,000	3.351	19.0	21.8	25.3	35.5
		100	144,000	6.701	68.7	78.8	91.4	128.
		150	216,000	10.052	146.	167.	194.	271.
		200	288,000	13.402	248.	284.	330.	462.
		250	360,000	16.753	375.	430.	499.	699.
		300	432,000	20.103	526.	603.	699.	980.
3	3.068	10	14,400	0.434	0.336	0.385	0.446	0.626
		15	21,600	.651	.711	.816	.946	1.33
		20	28,800	.868	1.21	1.39	1.61	2.26
		25	36,000	1.085	1.83	2.10	2.44	3.41
		50	72,000	2.170	6.01	7.58	8.79	12.3
		100	144,000	4.340	23.9	27.4	31.7	44.5
		200	288,000	8.680	86.1	98.8	115.	161.
		300	432,000	13.020	182.	209.	243.	340.
		400	576,000	17.360	311.	357.	414.	580.
		500	720,000	21.699	470.	539.	625.	876.
3½	3.548	10	14,400	0 325	0.165	0.190	0.220	0.308
		15	21,600	.487	.350	.402	.466	.653
		20	28,800	.649	.597	.684	.794	1.11
		25	36,000	.811	.902	1.03	1.20	1.68
		50	72,000	1.623	3.26	3.73	4.33	6.07
		100	144,000	3.245	11.8	13.5	15.6	21.9
		200	288,000	6.490	42.4	48.7	56.4	79.1
		300	432,000	9.735	89.9	103.	120.	168.
		400	576,000	12.980	153.	176.	204.	286.
		500	720,000	16.225	231.	266.	308.	432.
		600	864,000	19.470	324.	372.	432.	605.
4	4.026	20	28,800	0.304	0 322	0.370	0 429	0.601
		25	36,000	.630	.487	.559	.648	.909
		30	43,200	.756	.683	.784	.909	1.27
		40	57,600	1.008	1.16	1.33	1.55	2.17
		50	72,000	1.260	1.76	2.02	2.34	3.28
		100	144,000	2.520	6.35	7.28	8.45	11.8
		200	288,000	5.040	22.9	26.3	30.5	42.7
		300	432,000	7.561	48.6	55.7	64.6	90.6
		400	576,000	10.081	82.7	94.9	110.	154.
		500	720,000	12.601	125.	143.	166.	233.
		600	864,000	15.121	175.	201.	233.	327.
		800	1,152,000	20.162	299.	343.	397.	557.

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
5	5.047	30	43,200	0.481	0.227	0.261	0.302	0.424
		40	57,600	.642	.387	.441	.515	.722
		50	72,000	.802	.585	.671	.779	1.09
		100	144,000	1.604	2.11	2.42	2.81	3.94
		200	288,000	3.208	7 63	8.75	10.1	14.2
		300	432,000	4.812	16.2	18.5	21.5	30.1
		400	576,000	6.416	27 5	31.6	36.6	51.3
		500	720,000	8.020	41.6	47 7	55.3	77.6
		750	1,080,000	12.030	88.2	101.	117.	164.
		1000	1,440,000	16.040	150.	172.	200.	280.

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
6	6.065	50,000	0.0774	0.386	0.122	0.140	0.162	0.227
		60,000	0.928	.463	.171	.196	.227	.318
		80,000	.124	.617	.291	.333	.387	.542
		100,000	.155	.771	.439	.504	.585	.819
		200,000	.309	1.542	1.59	1.82	2.11	2.96
		300,000	.464	2.314	3.36	3 85	4.47	6.27
		400,000	.619	3.085	5.72	6.57	7.62	10.7
		600,000	.928	4.627	12.1	13.9	16.1	22.6
		800,000	1.238	6.170	20.7	23.7	27.5	38.5
		1,000,000	1.547	7.742	31.2	35.8	41.6	58.2
		1,500,000	2.321	11.568	66.2	75.9	88.1	123.
		2,000,000	3.094	15.424	113.	129.	150.	210.
8	7.981	200,000	0.309	0.891	0.416	0.478	0.554	0.777
		300,000	.464	1.336	.882	1.01	1.17	1.65
		400,000	.619	1.781	1.50	1.72	2.00	2.80
		500,000	.774	2.227	2.27	2.61	3.02	4.24
		750,000	1.160	3.340	4.82	5.52	6.41	8.98
		1,000,000	1.547	4.454	8.20	9.41	10.9	15.3
		1,500,000	2.321	6.680	17.4	19.9	23.1	32.4
		2,000,000	3.094	8.907	29.6	34.0	39.4	55.2
		3,000,000	4.642	13.361	62.7	72.0	83.5	117.
10	10.020	300,000	0.464	0.848	0.291	0.334	0.388	0.543
		400,000	.619	1.130	.496	.569	.660	.926
		500,000	.774	1.413	.750	.861	.998	1.40
		750,000	1.160	2.119	1.59	1.82	2.12	2.96
		1,000,000	1.547	2.825	2.71	3.11	3.60	5.05
		2,000,000	3.094	5.651	9.78	11.2	13.0	18.2

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
10	10.020	3,000,000	4.642	8.476	20.7	23.8	27.6	38.6
		4,000,000	6.189	11.302	35.3	40.5	47.0	65.8
		5,000,000	7.736	14.127	53.4	61.2	71.0	99.5
12	12.000	300,000	0.464	0.591	0.121	0.139	0.161	0.226
		400,000	.619	.788	.206	.237	.274	.385
		500,000	.774	.985	.312	.358	.415	.581
		1,000,000	1.547	1.970	1.13	1.29	1.50	2.10
		1,500,000	2.321	2.955	2.38	2.74	3.17	4.45
		2,000,000	3.094	3.940	4.06	4.66	5.40	7.58
		3,000,000	4.642	5.919	8.61	9.87	11.5	16.1
		5,000,000	7.736	9.850	22.2	25.4	29.5	41.3
		7,500,000	11.60	14.775	47.0	53.9	62.5	87.6
		10,000,000	15.47	19.700	80.0	91.8	106.	149.
14 O D	13.250	500,000	0.774	0.808	0.192	0.221	0.256	0.359
		1,000,000	1.547	1.616	.695	.797	.924	1.30
		2,000,000	3.094	3.232	2.51	2.88	3.34	4.68
		3,000,000	4.642	4.847	5.31	6.09	7.07	9.91
		5,000,000	7.736	8.079	13.7	15.7	18.2	25.5
		7,500,000	11.60	12.119	29.0	33.3	38.6	54.1
		10,000,000	15.47	16.158	49.4	56.6	65.7	92.1
		12,500,000	19.34	20.198	74.7	85.6	99.3	139.
16 O D	15.250	750,000	1.160	0.915	0.206	0.236	0.274	0.383
		1,000,000	1.547	1.220	.350	.402	.466	.653
		2,000,000	3.094	2.440	1.26	1.45	1.68	2.36
		3,000,000	4.642	3.659	2.68	3.07	3.56	5.00
		5,000,000	7.736	6.099	6.90	7.91	9.18	12.9
		7,500,000	11.60	9.148	14.6	16.8	19.4	27.3
		10,000,000	15.47	12.198	24.9	28.6	33.1	46.4
		15,000,000	23.21	18.297	52.8	60.5	70.2	98.4
18 O D	17.182	1,000,000	1.547	.961	0.196	0.225	0.261	0.365
		2,000,000	3.094	1.922	.707	.811	.941	1.32
		3,000,000	4.642	2.883	1.50	1.72	1.99	2.79
		5,000,000	7.736	4.805	3.86	4.43	5.13	7.20
		7,500,000	11.60	7.207	8.18	9.38	10.9	15.2
		10,000,000	15.47	9.609	13.9	16.0	18.5	26.0
		15,000,000	23.21	14.414	29.5	33.9	39.3	55.0
		20,000,000	30.94	19.218	50.3	57.7	66.9	93.8
20 O D	19.182	1,000,000	1.547	0.771	0.115	0.131	0.152	0.214
		2,000,000	3.094	1.542	.414	.475	.550	.771
		3,000,000	4.642	2.313	.876	1.01	1.17	1.63
		5,000,000	7.736	3.855	2.26	2.59	3.00	4.21
		7,500,000	11.60	5.782	4.78	5.49	6.36	8.92
		10,000,000	15.47	7.710	8.15	9.35	10.8	15.2
		15,000,000	23.21	11.565	17.3	19.8	23.0	32.2
		20,000,000	30.94	15.419	29.4	33.7	39.1	54.8

Table 16

Loss of Head in Pipe by Friction for Large Diameter Pipe Listed by I. D. Sizes, Calculated by Hazen-Williams Formula

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
22	1.8333	1	1.547	0.586	0.059	0.067	0.078	0.110
		2.5	3.868	1.465	.321	.368	.427	.598
		5	7.736	2.931	1.16	1.33	1.54	2.16
		7.5	11.60	4.396	2.45	2.81	3.26	4.57
		10	15.47	5.861	4.18	4.79	5.56	7.79
		15	23.21	8.792	8.86	10.2	11.8	16.5
		20	30.94	11.722	15.1	17.3	20.1	28.1
		25	38.68	14.653	22.8	26.2	30.3	42.5
24	2.0000	2	3.094	0.985	0.139	0.159	0.185	0.259
		5	7.736	2.462	.758	.869	1.01	1.41
		7.5	11.60	3.694	1.61	1.84	2.14	2.99
		10	15.47	4.925	2.74	3.14	3.64	5.10
		15	23.21	7.387	5.80	6.65	7.71	10.8
		20	30.94	9.850	9.87	11.3	13.1	18.4
		25	38.68	12.312	14.9	17.1	19.9	27.8
		30	46.42	14.775	20.9	24.0	27.8	39.0
26	2.1667	2	3.094	0.839	0.094	0.108	0.125	0.175
		5	7.736	2.098	.513	.589	.683	.957
		7.5	11.60	3.147	1.09	1.25	1.45	2.03
		10	15.47	4.196	1.85	2.12	2.46	3.45
		15	23.21	6.295	3.93	4.50	5.22	7.32
		20	30.94	8.393	6.69	7.67	8.90	12.5
		25	38.68	10.491	10.1	11.6	13.4	18.8
		30	46.42	12.589	14.2	16.3	18.8	26.4
28	2.3333	2	3.094	0.724	0.066	0.075	0.087	0.122
		5	7.736	1.809	.358	.410	.476	.667
		7.5	11.60	2.714	.758	.869	1.01	1.41
		10	15.47	3.618	1.29	1.48	1.72	2.41
		15	23.21	5.428	2.74	3.14	3.64	5.10
		20	30.94	7.237	4.66	5.35	6.20	8.69
		25	38.68	9.046	7.05	8.08	9.37	13.1
		30	46.42	10.855	9.88	11.3	13.1	18.4
30	2.5000	5	7.736	1.576	0.256	0.293	0.340	0.477
		10	15.47	3.152	.923	1.06	1.23	1.72
		15	23.21	4.728	1.96	2.24	2.60	3.65
		20	30.94	6.304	3.33	3.82	4.43	6.21
		25	38.68	7.880	5.03	5.78	6.70	9.39
		30	46.42	9.456	7.06	8.10	9.39	13.2
		35	54.15	11.032	9.39	10.8	12.5	17.5
		40	61.89	12.608	12.0	13.8	16.0	22.4
36	3.0000	5	7.736	1.094	0.105	0.121	0.140	0.196
		10	15.47	2.189	.380	.436	.505	.708
		15	23.21	3.283	.804	.923	1.07	1.50
		20	30.94	4.378	1.37	1.57	1.82	2.56
		30	46.42	6.567	2.90	3.33	3.86	5.41
		40	61.89	8.756	4.95	5.67	6.58	9.22
		50	77.36	10.944	7.48	8.58	9.95	13.9
		60	92.83	13.133	10.5	12.0	13.9	19.5

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
42	3.50	5	7.736	0.804	0.050	0.057	0.066	0.093
		10	15.47	1.608	.179	.206	.238	.334
		15	23.21	2.412	.380	.436	.505	.708
		20	30.94	3.216	.647	.742	.861	1.21
		30	46.42	4.824	1.37	1.57	1.82	2.56
		40	61.89	6.433	2.34	2.68	3.11	4.35
		50	77.36	8.041	3.53	4.05	4.70	6.58
		75	116.0	12.061	7.48	8.58	9.95	13.9
48	4.00	5	7.736	0.616	0.026	0.030	0.034	0.048
		10	15.47	1.231	.094	.107	.124	.174
		20	30.94	2.462	.338	.387	.449	.630
		30	46.42	3.694	.715	.821	.952	1.33
		40	61.89	4.925	1.22	1.40	1.62	2.27
		50	77.36	6.156	1.84	2.11	2.45	3.44
		75	116.0	9.234	3.90	4.48	5.19	7.28
		100	154.7	12.312	6.65	7.63	8.85	12.4
54	4.50	10	15.47	0.973	0.053	0.060	0.070	0.098
		20	30.94	1.946	.190	.218	.253	.353
		30	46.42	2.919	.403	.462	.536	.752
		40	61.89	3.891	.687	.788	.913	1.28
		50	77.36	4.864	1.04	1.19	1.38	1.94
		75	116.0	7.296	2.20	2.52	2.93	4.10
		100	154.7	9.728	3.75	4.30	4.98	6.99
		125	193.4	12.160	5.66	6.50	7.54	10.6
60	5.00	10	15.47	0.788	0.032	0.036	0.042	0.059
		20	30.94	1.576	.114	.131	.151	.213
		30	46.42	2.364	.241	.277	.321	.452
		40	61.89	3.152	.411	.471	.547	.768
		50	77.36	3.940	.621	.713	.827	1.16
		75	116.0	5.910	1.32	1.51	1.75	2.45
		100	154.7	7.880	2.24	2.57	2.98	4.18
		125	193.4	9.850	3.39	3.89	4.51	6.33
66	5.50	10	15.47	0.651	0.020	0.023	0.026	0.037
		20	30.94	1.302	.072	.082	.095	.133
		30	46.42	1.954	.152	.174	.202	.283
		50	77.36	3.256	.391	.448	.520	.728
		75	116.0	4.884	.828	.949	1.10	1.54
		100	154.7	6.512	1.41	1.62	1.88	2.63
		125	193.4	8.140	2.13	2.44	2.84	3.97
		150	232.1	9.769	2.99	3.43	3.97	5.57
72	6.00	10	15.47	0.547	0.013	0.015	0.017	0.024
		25	38.68	1.368	.071	.081	.094	.133
		50	77.36	2.736	.256	.293	.340	.477
		75	116.0	4.104	.542	.621	.721	1.01
		100	154.7	5.472	.923	1.06	1.23	1.73
		125	193.4	6.840	1.40	1.60	1.86	2.60
		150	232.1	8.208	1.96	2.24	2.60	3.65
		175	270.8	9.576	2.60	2.98	3.46	4.85

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Cubic feet per second	Million gallons per 24 hours		c=140	c=130	c=120	c=100
78	6.50	25	16.16	0.753	0.021	0.025	0.028	0.040
		50	32.32	1.507	.077	.089	.103	.144
		75	48.47	2.260	.163	.188	.217	.305
		100	64.63	3.014	.278	.319	.371	.519
		150	96.95	4.520	.590	.677	.785	1.10
		200	129.3	6.027	1.01	1.15	1.34	1.87
		250	161.6	7.534	1.52	1.74	2.02	2.83
		300	193.9	9.041	2.13	2.44	2.83	3.97
84	7.00	25	16.16	0.650	0.015	0.017	0.020	0.028
		50	32.32	1.299	.054	.062	.072	.100
		75	48.47	1.949	.114	.131	.152	.212
		100	64.63	2.598	.194	.223	.258	.362
		150	96.95	3.898	.411	.472	.547	.767
		200	129.3	5.197	.701	.804	.932	1.31
		250	161.6	6.496	1.06	1.22	1.41	1.98
		300	193.9	7.795	1.48	1.70	1.98	2.77
90	7.50	25	16.16	0.566	0.011	0.012	0.014	0.020
		50	32.32	1.132	.038	.044	.051	.072
		75	48.47	1.698	.081	.093	.108	.152
		100	64.63	2.264	.139	.159	.185	.259
		150	96.95	3.395	.294	.337	.391	.548
		200	129.3	4.527	.501	.574	.666	.934
		300	193.9	6.791	1.06	1.22	1.41	1.98
		400	258.5	9.054	1.81	2.07	2.40	3.37
96	8.00	25	16.16	0.497	0.008	0.009	0.010	0.014
		50	32.32	0.995	.028	.032	.037	.052
		100	64.63	1.989	.101	.116	.135	.189
		150	96.95	2.984	.215	.246	.286	.400
		200	129.3	3.979	.366	.419	.486	.682
		300	193.9	5.968	.775	.889	1.03	1.44
		400	258.5	7.958	1.32	1.51	1.76	2.46
		500	323.2	9.947	2.00	2.29	2.65	3.72

The Scobey Formula

Fred C. Scobey,* Senior Irrigation Engineer of the Division of Agricultural Engineering, U. S. Department of Agriculture, offers the following formulas which he says "include viscosity influence for a temperature of 15° C. (59° F.) and differentiate between various types and classes of sheet and plate metal pipe by means of coefficients, which are themselves constant throughout the whole range of sizes and velocities for a given class of pipe"

$$hf = \frac{K_s v^{1.9}}{D^{1.1}}$$

$$v = \frac{hf^{0.526} D^{0.58}}{K_s^{0.526}}$$

where hf = Loss of head in feet due to friction per 1000 feet of pipe.
D = Mean inside diameter of pipe in feet.
v = Mean velocity of the water in feet per second.
K_s = General coefficient. (K'_s is this value for new pipe.)

Scobey limited his study to pipe of nominal size, four inch and larger, and assumed that the interior of all pipe would be chemically protected with a coating which would form the true interior surface, at least during the first years of the life of the conduit.

He divides sheet and plate metal pipe into three major classes:

Class 1—"Full-riveted" pipe, having both longitudinal and girth seams held by one or more lines of rivets with projecting

*United States Department of Agriculture Technical Bulletin No. 150 "The Flow of Water in Riveted Steel and Analogous Pipes" (1930).

Table 17

Loss of Head in Pipe by Friction for National Duroline Pipe* Calculated by the Hazen-Williams Formula

Pipe size, inches	Average inside diameter, inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (hr) ($c = 148$)
½	0.484	1	1,440	1.74	35.0
		2	2,880	3.48	126.0
		3	4,320	5.23	265.0
		4	5,760	6.97	455.0
		5	7,200	8.72	685.0
		6	8,640	10.46	970.0
		8	11,520	13.95	1650.0
		10	14,400	17.44	2500.0
¾	0.686	2	2,880	1.73	22.8
		3	4,320	2.60	48.0
		4	5,760	3.47	82.0
		5	7,200	4.34	124.0
		6	8,640	5.21	173.0
		8	11,520	6.94	295.0
		10	14,400	8.68	443.0
		15	21,600	13.02	946.0
		20	28,800	17.36	1590.0
1	0.896	3	4,320	1.52	13.2
		4	5,760	2.03	22.2
		5	7,200	2.54	34.5
		6	8,640	3.05	47.5
		8	11,520	4.07	81.0
		10	14,400	5.08	120.0
		12	17,280	6.10	170.0
		14	20,160	7.12	225.0
		16	23,040	8.14	290.0
		20	28,800	10.16	432.0
		25	36,000	12.70	630.0
		30	43,200	15.24	925.0
1¼	1.175	4	5,760	1.18	5.8
		5	7,200	1.47	9.0
		6	8,640	1.77	12.6
		7	10,080	2.07	16.7
		8	11,520	2.36	21.5
		10	14,400	2.95	32.5
		12	17,280	3.55	45.5
		14	20,160	4.14	59.0
		16	23,040	4.73	77.0
		18	25,920	5.32	96.0
1¼	1.175	20	28,800	5.91	116.0
		25	36,000	7.39	175.0
		30	43,200	8.87	245.0
		40	57,600	11.80	420.0
		60	86,400	17.70	880.0
1½	1.405	4	5,760	0.82	2.60
		5	7,200	1.03	3.95
		6	8,640	1.24	5.28
		7	10,080	1.44	7.3
		8	11,520	1.65	9.4
		9	12,960	1.86	11.6
		10	14,400	2.06	14.2
		12	17,280	2.48	19.8
		14	20,160	2.89	26.4
		16	23,040	3.31	34.5
		18	25,920	3.72	42.0
		20	28,800	4.13	51.0
		22	31,680	4.55	61.0
		24	34,560	4.96	72.0
		26	37,440	5.38	83.0
		28	40,320	5.79	95.0
		30	43,200	6.20	108.0
		35	50,400	7.24	135.0
		40	57,600	8.27	176.0
		50	72,000	10.34	266.0
		75	108,000	15.51	562.0
		100	144,000	20.69	960.0
2	1.780	6	8,640	0.77	1.66
		8	11,520	1.03	2.82
		10	14,400	1.28	4.30
		12	17,280	1.54	6.0
		14	20,160	1.80	8.0
		16	23,040	2.06	10.2
2	1.780	18	25,920	2.32	12.7
		20	28,800	2.57	15.5
		25	36,000	3.22	23.2
		30	43,200	3.86	33.0
		35	50,400	4.51	44.0
		40	57,600	5.15	56.0
		45	64,800	5.80	77.0
		50	72,000	6.44	84.0
		55	79,200	7.09	100.0
		60	86,400	7.73	117.0
		65	93,600	8.37	135.0
		70	100,800	9.02	157.0
		75	108,000	9.66	177.0
		100	144,000	12.89	302.0
		150	216,000	19.33	570.0
2½	2.182	8	11,250	0.68	1.05
		10	14,400	.85	1.58
		12	17,280	1.02	2.25
		16	23,040	1.37	3.85
		25	36,000	2.14	8.6
		50	72,000	4.29	31.5
		100	144,000	8.58	113.0
		150	216,000	12.87	240.0
		200	288,000	17.16	410.0
		250	360,000	21.45	620.0
3	2.725	10	14,400	0.55	0.54
		15	21,600	.82	1.16
		20	28,800	1.10	1.95
		25	36,000	1.37	2.95
		50	72,000	2.75	10.6
		80	115,200	4.40	25.3
		100	144,000	5.50	38.5
		160	230,400	8.80	90.0
		200	288,000	11.00	136.0
		300	432,000	16.50	290.0
		400	576,000	22.00	500.0
		500	720,000	27.50	750.0
3½	3.205	10	14,400	0.39	0.24
		15	21,600	.59	.52
		20	28,800	.79	.88
		25	36,000	.99	1.34
		50	72,000	1.98	4.8
		80	115,200	3.18	11.5
		100	144,000	3.97	17.5
		160	230,400	6.36	41.5
		200	288,000	7.95	63.0
		300	432,000	11.93	135.0
		400	576,000	15.90	225.0
		500	720,000	19.88	340.0
4	3.620	20	28,800	0.62	0.49
		25	36,000	.77	.74
		30	43,200	.93	1.04
		50	72,000	1.55	2.68
		80	115,200	2.49	6.4
		100	144,000	3.11	9.7
		160	230,400	4.98	23.4
		200	288,000	6.23	35.0
		300	432,000	9.35	72.2
		400	576,000	12.46	124.0
		500	720,000	15.58	187.0
5	4.548	30	43,200	0.59	0.34
		40	57,600	.79	.58
		50	72,000	.98	.87
		80	115,200	1.58	2.10
		100	144,000	1.97	3.15
		160	230,400	3.16	7.7
		200	288,000	3.95	11.5
		300	432,000	5.92	24.2
		400	576,000	7.90	41.2
		500	720,000	9.87	61.8
		750	1,080,000	14.81	131.0

Pipe size, inches	Average inside diameter, inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (hr) ($c = 148$)
6	5.440	50,000	.0774	0.47	0.20
		60,000	.0928	.57	.26
		80,000	.1238	.76	.44
		100,000	.1547	.95	.66
		140,000	.2166	1.34	1.25
		200,000	.3094	1.91	3.42
		300,000	.4642	2.87	5.2
		400,000	.619	3.83	8.7
		500,000	.774	4.79	13.2
		600,000	.928	5.75	18.5
6	5.440	800,000	1.238	7.67	31.5
		1,000,000	1.547	9.58	48.0
		1,500,000	2.321	14.37	100.0
		2,000,000	3.094	19.17	170.0
8	7.446	200,000	.3094	1.02	0.53
		300,000	.4642	1.53	1.12
		360,000	.557	1.84	1.57
		400,000	.619	2.04	1.92
		500,000	.774	2.55	2.88
		600,000	.928	3.06	4.05
		700,000	1.083	3.58	5.4
		800,000	1.238	4.09	6.9
		900,000	1.392	4.60	8.6
		1,000,000	1.547	5.11	10.5
		1,200,000	1.857	6.13	14.6
		1,500,000	2.321	7.67	22.0
		2,000,000	3.094	10.23	37.0
		3,000,000	4.642	15.34	79.0
8	7.356	200,000	.3094	1.04	0.56
		300,000	.4642	1.57	1.18
		400,000	.619	2.09	2.00
		500,000	.774	2.62	3.05
		600,000	.928	3.14	4.30
		700,000	1.083	3.66	5.7
		800,000	1.238	4.19	7.3
		1,000,000	1.547	5.24	11.2
		1,500,000	2.321	7.86	23.8
		2,000,000	3.094	10.48	40.0
		3,000,000	4.642	15.72	84.0
10	9.443	300,000	.4642	0.95	0.35
		400,000	.619	1.27	.60
		500,000	.774	1.59	.90
		600,000	.928	1.90	1.26
		750,000	1.160	2.38	1.92
		1,000,000	1.547	3.18	3.25
		1,500,000	2.321	4.77	6.9
		2,000,000	3.094	6.36	11.8
		3,000,000	4.642	9.54	25.0
		4,000,000	6.188	12.72	42.5

*Pipe lined with a highly resistant cement-base composition lining.—Ed.

heads. From the capacity standpoint, pipe with countersunk rivet heads on the interior belong in *Class 3*.

Class 2—"Girth-riveted" pipe, having no retarding rivet heads in the longitudinal seams, but having the same girth seams as full-riveted pipe.

Class 3—"Continuous-interior" pipe, having the interior surface unmarred by plate offsets or by projecting rivet heads in either longitudinal or girth seams. Not necessarily described as "smooth."

For these classes Scobey suggests the following coefficients for new pipe:

Class 1a, $K'_s = 0.38$ for new sheet metal pipe up to three-sixteenths of an inch thick.

Class 1b, $K'_s = 0.44$ for new plate metal pipe on three-sixteenths to seven-sixteenths of an inch thick, with either taper or cylinder joints.

Class 1c, $K'_s = 0.48$ for new plate metal pipe from one-half inch up, with either taper or cylinder joints, and for plate from one-fourth to seven-sixteenths of an inch thick when butt-jointed.

Class 1d, $K'_s = 0.52$ for new butt-strap pipe of plate from one-half inch up.

Class 2d, $K'_s = 0.34$ for new girth-riveted pipe. This includes all sheet and plate metal pipe with continuous seamed longitudinal joints but with girth joints, particularly field joints, made with the usual rivet heads inside the pipe.

Class 3, $K'_s = 0.32$ for new continuous-interior pipe. This class comprises all type of sheet and plate metal pipe that offer a practically uniform interior surface of relative smoothness. "Continuous-interior" is offered as descriptive of an interior surface unbroken by rivet heads or appreciable shell-thickness offsets. Use of the apparently obvious synonym "smooth" has purposely been avoided, as this description might hold only while the pipe is new.

NOTE: Although Scobey confines his paper to the discussion of sheet and plate metal pipe, *Classes* 2 and 3 also apply to seamless pipe as well as to lap-weld, hammer-weld, and electric-weld pipe.

It should be noted that the coefficients (K'_s) given above

are for new pipe. Concerning the deterioration of carrying capacity with age, Scobey states:

"It has long been appreciated that all metal pipe deteriorates in carrying capacity; the rate of decrease being dependent on the efficiency of the pipe coating, the composition and treatment of the pipe material, and the activity of the water conveyed in the pipe. Filtered and treated water causes less deterioration than raw water. Long lines deteriorate more rapidly at the upper ends than at the lower ends. "So far as available data indicate, the increase in the value of K_s with age, is expressed by the formula:

$$K_s = K'_s e^{0.033t}$$

where e = Base of Naperian logarithms (2.7183).
t = Age of pipe in years.
When t is zero, then K_s becomes K'_s."

[NOTE: Tables showing various values of K_s and corresponding losses of head at various velocities and also values of $v^{1.9}$ have had to be omitted. For a copy of these address National Tube Co., Pittsburgh, Pa., asking for Technical Bulletin No. 21. —Ed.]

Fig. 36, which was taken from United States Department of Agriculture Technical Bulletin No. 150, will be found useful in making estimates and preliminary studies. It gives the relation between discharge, pipe diameter, velocity, and loss of head for various values of the coefficient K_s. Values of K_s for ages of 0 to 50 years corresponding to various values of K'_s are also given.

The lower age diagram on the chart is based on the formula $K_s = K'_s e^{0.133t}$ and is to be used for aggressive waters. The upper age diagram is based on the formula $K_s = K'_s e^{0.01t}$ and is intended for use where the waters are known to be non-aggressive.

The following example will illustrate the method of using this chart:

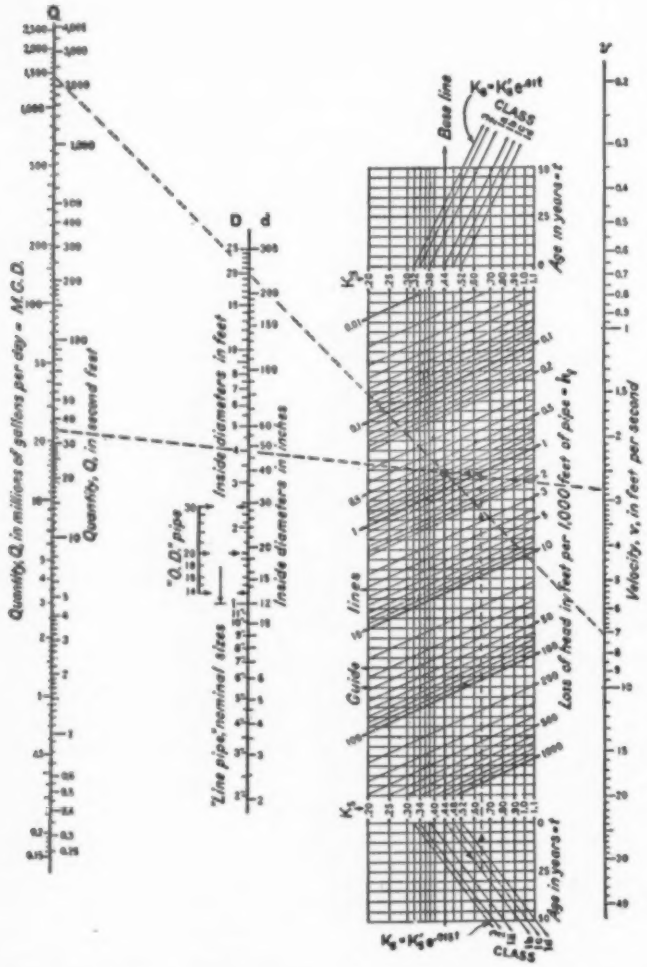


Fig. 36 — Chart Showing Relation Between Discharge Pipe Diameter, Velocity and Loss of Head for Various Values of the Coefficient K_s and K_{s1} in Scobey Formula

Table 21

Special Losses of Head in Terms of $v^2/2g$ (From Hydraulics by Ernest W. Schoder and Francis M. Dawson—Second Edition, 1934, with Modifications)

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Entrance	
Square-edged entry. Upstream end of pipe perpendicular to, and flush with inside face of reservoir wall	0.50
Projecting pipe at entry or re-entrant pipe end	1.00
Well-rounded entry	0.02 to 0.05
Curves and Fittings	
Easy curves or bends of very large radius, and smooth inside, of same inside diameter throughout as the pipe line. Excess loss over same length of straight pipe	0.05 to 0.15
90-degree curves, fairly smooth, same inside diameter as pipe; Radius of center line = diameter of pipe	0.50
Radius of center line = 2 to 8 times diameter of pipe	0.25
90-degree common screw end pipe elbows, short turn, inside larger than pipe	0.75
Tees, common screw end, full-size branch, flow deviated 90 degrees	1.50
Square elbow (intersection of two cylinders, corner not rounded at outside or inside of curve.)	1.25
Obtuse-angled elbows, (deflection of pipe less than 90 degrees); multiply values for square elbow or 90-degree curve by $\left(\frac{\text{deflection, degrees}}{90 \text{ degrees}}\right)^2$	
Water Meters (Subject to much variation)	
Disk or "wobble-disk" type	3.4 to 10
Rotary type (star or cog-wheel-shaped disk as piston)	10
Reciprocating piston type (like a piston pump)	15
Turbine-wheel type (double flow, balanced)	5 to 7.5
Diaphragm and Orifice Meters	
Diaphragm of thin material across pipe, with concentric hole, or an inside projecting washer or gasket, or a "burr", due to cutting pipe with a wheel cutter: Diameter of hole = 0.91 × diameter of pipe	0.34
Diameter of hole = 0.80 × diameter of pipe	1.88
(Note that $v^2/2g$ in this particular case refers to pipe, not to the area of opening, nor to the contracted stream through opening.)	
Nozzles	
Nozzles: when the coefficient of velocity and discharge ranges from 0.99 to 0.975, the loss of head ranges from	0.02 to 0.05 (Where v is the velocity of the issuing jet)

*Note: Except where otherwise noted, v is the mean velocity in the pipe.

Assume that it is desired to know what conditions will prevail in a pipe line constructed of full-riveted pipe (*Class* 1*b*) after carrying aggressive waters for a period of 25 years.

From page 45 the coefficient K_s for new pipe of *Class* 1*b* is found to be 0.44. On the lower age diagram follow the diagonal line representing $K_s = 0.44$ (at 0 age) until it intersects the horizontal line representing an age of 25 years. From this point of intersection proceed vertically on the dashed line (which represents $K_s = 0.64$) until it intersects the slope line of 1 foot per 1000 feet of pipe. From this point follow the guide lines to the vertical base line. Using this point (marked on the chart by a circle) as a pivot, a straight edge will give simultaneous values of discharge (Q) diameter (D or d) and velocity (v). This is illustrated by dashed lines for 20 feet and 4 feet inside diameter pipe. The dashed line through the pivot point and the point representing pipe of 20 feet inside diameter shows that a discharge of 2250 cubic feet per second and a velocity of 7.2 feet per second can be expected. The other dashed line through the pivot point and through the point representing pipe 4 feet inside diameter indicates a discharge of 36 cubic feet per second and a velocity of 2.8 feet per second.

Special Losses of Head

Curves, elbows, tees, meters, enlargements, contractions, etc., in a pipe line cause losses of head, which, if of consequence, must be allowed for in addition to the loss of head ordinarily encountered in straight pipe of uniform cross section.

Special losses may be expressed as equivalent lengths of straight pipe which would cause the same loss of head, or as decimals or multiples of $v^2/2g$, where v is the mean velocity in the pipe. For any particular special fittings, experiments show that the loss of head is not in all cases a constant fraction of

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Venturi Meter Tubes	
The purpose of the diverging outlet cone is to decelerate the velocity and regain the pressure dropped at the throat.	v = throat velocity; g = acceleration of gravity; d_1 = inlet diam. Venturi Tube; d_2 = throat diam.
For Herschel Standard Venturi Tubes total divergence angle 5 degrees (approx.)	For $\frac{d_2}{d_1}$ = 0.7 0.5 0.3
For Venturi Tubes total divergence angle 15 degrees	0.11 0.11 0.13
(The lower values go with large throats, and the larger values with small throats whose diameter is from ⅓ to ½ the diameter of the pipe.)	0.15 0.18 0.24
Sudden Enlargement	
Sudden enlargement, from a small pipe ending abruptly where a larger pipe begins, is found to involve loss of head fairly close in accordance with Borda's Formula which is: Loss of head = $\frac{(v_1-v_2)^2}{2g}$ (Note that this is not the difference of the velocity heads, but is the head corresponding to the difference of the velocities.) The above-stated formula may be written: Loss of head = $\left(1-\frac{A_1}{A_2}\right)^2 \frac{v_1^2}{2g}$, or for a circular or square pipe: Loss of head = $\left[1-\left(\frac{d_1}{d_2}\right)^2\right]^2 \times \frac{v_1^2}{2g}$ where A_1, v_1 and d_1 refer to the smaller upstream pipe, while the subscript 2 refers to the larger downstream pipe.	
Sudden Square-Edged Reductions	
Sudden square-edged reductions in pipes. When the sudden reduction of pipe is very large, say d_2/d_1=0.1, the loss of head is practically as given for square-edged entry, i.e., loss of head = $0.40v_2^2/2g$. For smaller reductions the value of K is smaller, but the experimental data of Weisbach (1855) and Brightmore (1907) do not agree. For ratios d_2/d_1 = 0.5, 0.75, and 0.9 the value K is about 0.33, 0.20 and 0.08, respectively. In this case the subscript 2 refers to the smaller downstream pipe, and K is the factor which, multiplied by $v_2^2/2g$, gives the loss of head.	

*Note: Except where otherwise noted, the v is mean velocity in the pipe.

Table 21—Concluded

Special Losses of Head in Terms of $v^2/2g$

$v^2/2g$, but that the fraction varies somewhat with the velocity. For most practical purposes, however, the values given in 21 may be relied on as safe average values.

Water Hammer

When a valve in a water line is closed while the water is flowing, the velocity of the water upstream from the valve is reduced and a dynamic pressure is exerted in addition to the normal static pressure. This dynamic pressure, commonly called "water hammer," is the result of the transformation of the kinetic energy of the moving mass of water into pressure energy which expends itself (unless relief devices are provided) by compressing the water and stretching the pipe walls. When a valve is closed suddenly, the magnitude of the dynamic pressure produced is frequently much greater than the static pressure on the line, and may cause fracture of the pipe or fittings.

Starting at the suddenly-closed valve, a wave of increased pressure is transmitted back through the pipe with constant velocity and intensity. When the pressure wave has traveled upstream to the end of the pipe, where there is a reservoir or large main, the elasticity of the compounded water and of the expanded pipe reverse the flow and a wave of normal pressure travels downstream, the flow being progressively reversed as the water expands.

If the water were incompressible and the pipe inelastic, the instantaneous closure of the valve would create an infinite pressure. Since it is impossible to close a valve instantaneously, it is apparent that a series of pressure waves is created, causing an increased pressure at the valve. If the valve is completely closed before the first pressure wave has time to return to the valves as a wave of low pressure, the pressure increases continually up to the time of complete closure and the resulting pressure is just the same as if the valve had been instantaneously closed. The velocity of the pressure wave depends upon the ratio of wall-thickness to inside pipe diameter and on the modulus of elasticity of the water and of the pipe material according to the formula:

$$S = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{E_w}+\frac{d}{E_p t}\right)}}$$

The head due to water hammer in excess of normal static head is proportional to the destroyed velocity and to the velocity of the pressure wave along the pipe. Since the intensity of the excess head depends upon the destroyed velocity, the same excess pressure is produced by suddenly reducing the velocity from 6 to 3 feet per second, as by entirely stopping a velocity of 3 feet per second. The excess head due to water hammer is given by the formula:

$$h = \frac{12\,v}{g\sqrt{\frac{w}{g}\left(\frac{1}{E_w}+\frac{d}{E_p t}\right)}}$$

where S = Velocity of pressure wave along pipe in feet per second.
w = Weight of water in pounds per cubic foot.
h = Head due to water hammer (in excess of static head).
g = Acceleration of gravity.
t = Wall-thickness of pipe in inches.
d = Inside diameter of pipe in inches.
E_p = Modulus of elasticity of pipe material in pounds per square inch.
E_w = Modulus of elasticity of water in pounds per square inch.
v = Destroyed velocity in feet per second.

By inserting values for g, w, E_w and E_p the two formulas may be simplified. Thus, if
g = 32.174 feet per second per second.
w = 62.4096 pounds per cubic foot (at 50° F.)
E_w = 300,000 pounds per square inch.
E_p = 29,000,000 pounds per square inch (for steel pipe)
the formulas reduce to:

$$S = \frac{4720}{\sqrt{1+.0103\frac{d}{t}}}$$

$$h = \frac{147\,v}{\sqrt{1+.0103\frac{d}{t}}}$$

If the flow is not checked rapidly, so that the wave from the first movement of the valve has time to travel upstream to the end and back again several times while the valve closing is in progress, the excess pressure is greatly reduced. Therefore, it is advisable to use slow closing valves or to provide air chambers or surge tanks in the line to absorb the shock due to water hammer.

Measurement of Flowing Water

Pitot Tubes

Pitot tubes are used to measure the velocity of flowing water. Such a tube consists essentially of a vertical tube, the lower end of which is bent at 90° so that its open end is directed against the current. The velocity of the flowing water causes the water to rise in the vertical leg of the pitot tube a distance above the free surface of the stream equal to the velocity head.

When a pitot tube is inserted into a pipe carrying water under pressure, the water will rise in the vertical leg of the tube a distance equal to the sum of the pressure head and the velocity head at the point where the tube is inserted. If a piezometer tube is tapped into the wall of the pipe at substantially the same point, the water will rise in this tube a distance equal to the pressure head at that point. The difference in the levels of the water in the two tubes will therefore be equal to the velocity head in the pipe at the point where the tubes are inserted. Fig. 37 shows such an arrangement. The height of the water in the pitot tube is equal to the sum of the pressure head, h_p, and the velocity head, h_v. The height of the water in the piezometer tube is equal to the pressure head, h_p. The

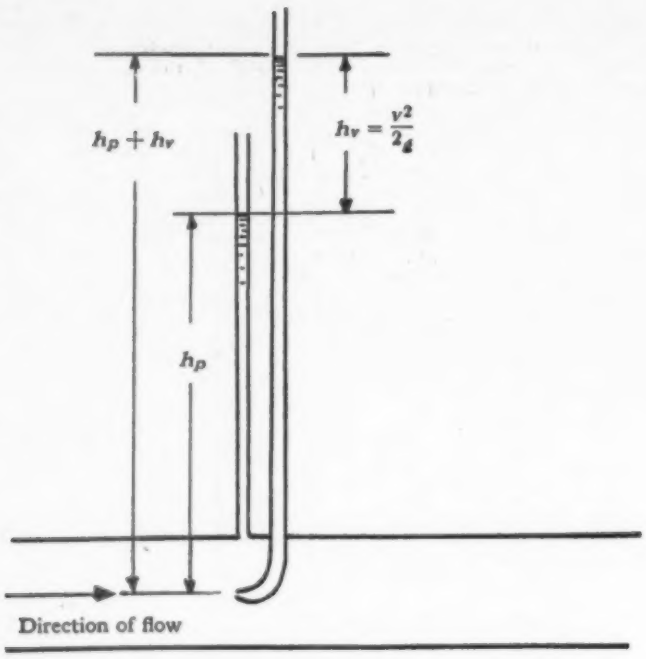


Fig. 37—Pitot Tube

difference in the height of the water in the two tubes is therefore equal to the velocity head, h_v.

Mercury columns or manometers may be used, instead of the water column, to determine the pressures.

In order to determine the discharge by use of a pitot tube, the cross section of the stream or pipe must be divided into one or more known areas, the velocity for each found, and hence the mean velocity of the entire cross section. The discharge is then found by multiplying the cross-sectional area by the mean velocity. In a straight length of pipe which extends upstream about 50 diameters from place of measurement without tees, valves, etc., the distribution of velocities is normal. Where normal distribution of velocities prevails, the ratio of mean velocity to center velocity (called the pipe coefficient) averages about 0.83.

Venturi Meters

The Venturi meter was invented by Clemens Herschel and was named by him for the inventor of the principle involved. It may be used to measure the discharge of water or other fluids contained in pipes which run full and under positive pressure.

The Venturi tube consists of a converging cone of steep taper, a diverging cone of more gradual taper, and a short cylindrical section called the throat, which connects the two cones at their smallest diameters. The essential parts of a Venturi meter are shown in Fig. 38. In this figure h_1 represents the pressure head in the pipe upstream for the Venturi meter, h_2 the pressure head at the throat, and h_3 the pressure head in the pipe downstream from the Venturi meter. The difference between h_1 and h_2 is hf and is the loss of head due to friction in the Venturi tube. The loss of head in a Venturi tube is usually quite small (see Table 21). Where the recovery of pressure is not important the converging cone may be very short or may even be omitted, forming a Venturi nozzle.

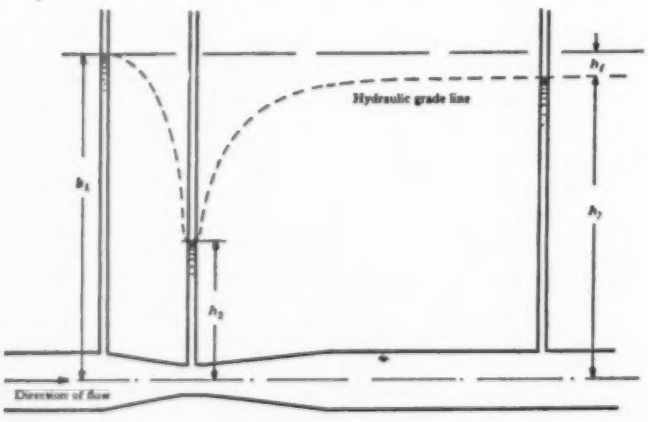


Fig. 38—Venturi Meter

Since the quantity of water flowing past any cross section of the tube is the same at any instant, the velocity at the small cross section of the throat will be greater than in the large cross section of the pipe upstream from the Venturi tube.

This greater velocity in the throat is obtained at the expense of the pressure head, so that h_2 is less than h_1. The dotted line in the figure represents the approximate hydraulic grade line and indicates the loss and recovery of pressure from h_1 to h_2.

The relation between the flow through a Venturi tube and the difference in pressure between the inlet and throat is given by the formula:

$$Q = C_v A_2 \sqrt{\frac{2gh_d}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_v A_2 \sqrt{\frac{2gh_d}{1-\left(\frac{D_2}{D_1}\right)^4}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Inside diameter of throat of Venturi tube in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of inside of throat of tube in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
h_d = Differential head in feet of water = $h_1 - h_2$.
C_v = Discharge coefficient of Venturi tube which varies from about 0.95 to 0.995.

The pressure differences ($h_1 - h_2$) may be measured by a simple glass U-tube containing mercury. Commercial Venturi tubes are usually provided with two annular chambers connected by vents with the inlet and throat, respectively, to obtain correct average pressures at these points. Various types of indicating, recording and integrating meters may be obtained for use with commercial Venturi tubes.

Pipe Orifices

Orifices in diaphragms inserted between pairs of flanges in straight portions of pipe lines have been found to be reliable measuring devices. The diaphragms are usually of thin noncorrodible metal and the orifices are accurately machined to size and beveled on the downstream side to keep the working edge thin.

Fig. 39 shows the essential parts of such a device. Two piezometer tubes are attached to the line, one at a distance of

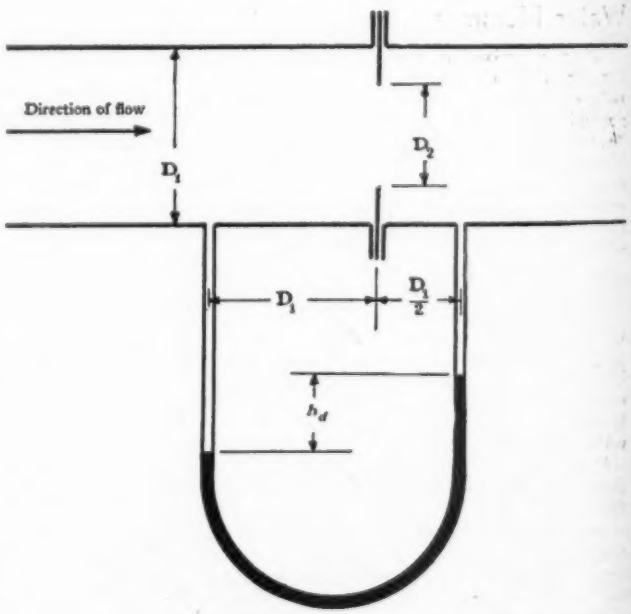


Fig. 39—Pipe Orifice

one pipe diameter upstream and the other one-half pipe diameter downstream from the plate. Either a differential gage, as shown in the figure, or open water columns may be used, depending upon the pressure. The rate of flow is a function of the differential pressure as indicated by the formula:

$$Q = C_o A_2 \sqrt{\frac{2gh_d}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_o A_2 \sqrt{\frac{2gh_d}{1-\left(\frac{D_2}{D_1}\right)^4}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Diameter of orifice in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of orifice in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
h_d = Differential head in feet of water = $h_1 - h_2$.
C_o = Discharge coefficient = about 0.606 for D_2/D_1 from 0.10 to 0.75.

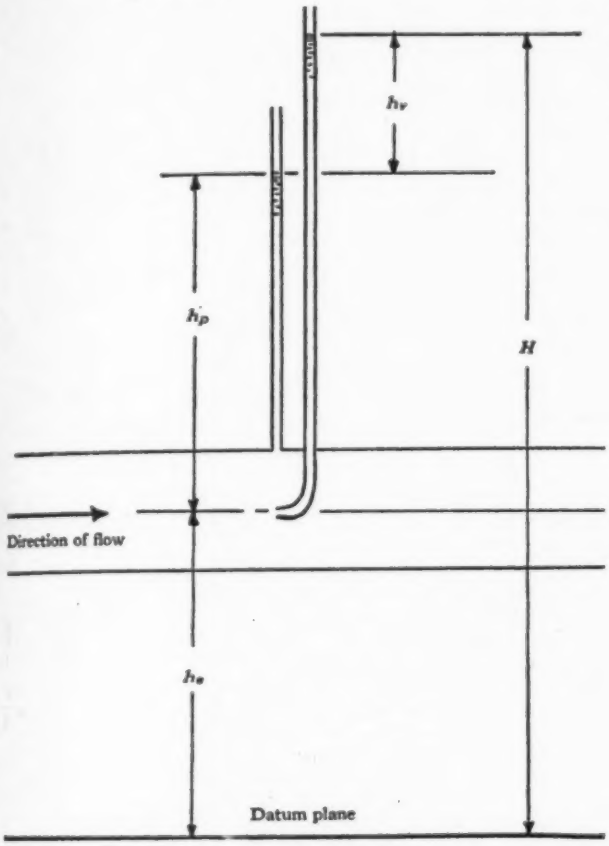


Fig. 40—Total Head

The orifice should be placed in a straight section of horizontal or vertical pipe and should be located as far as possible from bends, fittings, and valves. The diameter of the orifice should not be greater than 75 to 80 per cent of the inside diameter of the pipe. The loss of head in the pipe orifice is quite large and it is less reliable than the Venturi meter.

Water Power

The total available power of flowing water is given by the formula:

$$H.P. = \frac{QwH}{550} = 0.113472\,QH$$

where $H.P.$ = Horse Power.
Q = Discharge in cubic feet per second.
H = Total available head in feet.
w = Weight of one cubic foot of water (at 50° F. = 62.4096 pounds).

The total head may be made up of velocity head, pressure head, and potential head, or head due to actual height above the datum plane. Fig. 40 illustrates the three components of the total head.

The value of the velocity head is given by the expression:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Table 22
Horsepower for Various Heads of Water

Horse power for 1 cu. ft. of water per second under heads of 1 to 2,000 ft. Based on an efficiency of 80 per cent and weight of water at 50°F. = 62.4096 lb. per cubic foot.

(Horse power per cubic foot of water per second = $\frac{62.4096 \times 0.80 \times H}{550} = 0.0907776\,H$).

Head in feet (H)	Horse power	Head in feet (H)	Horse power	Head in feet (H)	Horse power	Head in feet (H)	Horse power
1	0.0907776	170	15.4322	420	38.1266	925	83.9693
2	.181555	180	16.3400	430	39.0344	950	86.2387
3	.272333	190	17.2477	440	39.9421	975	88.5082
4	.363110	200	18.1555	450	40.8499	1000	90.7776
5	.453888	210	19.0633	460	41.7577	1050	95.3165
6	.544666	220	19.9711	470	42.6655	1100	99.8554
7	.635443	230	20.8788	480	43.5732	1150	104.394
8	.726221	240	21.7866	490	44.4810	1200	108.933
9	.816998	250	22.6944	500	45.3888	1250	113.472
10	.907776	260	23.6022	525	47.6582	1300	118.011
20	1.81555	270	24.5100	550	49.9277	1350	122.550
30	2.72333	280	25.4177	575	52.1971	1400	127.089
40	3.63110	290	26.3255	600	54.4666	1450	131.628
50	4.53888	300	27.2333	625	56.7360	1500	136.166
60	5.44666	310	28.1411	650	59.0054	1550	140.705
70	6.35443	320	29.0488	675	61.2749	1600	145.244
80	7.26221	330	29.9566	700	63.5443	1650	149.783
90	8.16998	340	30.8644	725	65.8138	1700	154.322
100	9.07776	350	31.7722	750	68.0832	1750	158.861
110	9.98554	360	32.6799	775	70.3526	1800	163.400
120	10.8933	370	33.5877	800	72.6221	1850	167.939
130	11.8011	380	34.4955	825	74.8915	1900	172.477
140	12.7089	390	35.4033	850	77.1610	1950	177.016
150	13.6166	400	36.3110	875	79.4304	2000	181.555
160	14.5244	410	37.2188	900	81.6998	....	.....

Table 25—Pressure Equivalents

Units		Pounds per square inch	Pounds per square foot	Kilograms per square centimeter	Inches of mercury at 32° F.	Feet of water at 39.2° F.	Feet of water at 62° F.	Atmospheres
1 pound per square inch	=	1.	144.	0.0703067	2.0360	2.30671	2.30934	0.068044
1 pound per square foot	=	0.0069444	1.	0.0004882	0.014139	0.016019	0.016037	0.0004725
1 ounce per square inch	=	0.0625	9.	0.0043942	0.12725	0.144169	0.144334	0.0042528
1 kilogram per square centimeter	=	14.2234	2048.17	1.	28.9582	32.8092	32.8467	0.967820
1 kilogram per square meter	=	0.0014223	0.204817	0.0001	0.0028958	0.0032809	0.0032847	9.678×10^{-5}
1 inch of mercury at 32° F.	=	0.49117	70.7285	0.034533	1.	1.13299	1.13428	0.033421
1 inch of water at 39.2° F.	=	0.036127	5.20222	0.0025399	0.073552	0.083333	0.083428	0.0024582
1 inch of water at 62° F.	=	0.036085	5.19628	0.0025370	0.073468	0.083238	0.083333	0.0024554
1 foot of water at 39.2° F.	=	0.43352	62.4266	0.030479	0.88262	1.	1.00114	0.029498
1 foot of water at 62° F.	=	0.43302	62.3554	0.030444	0.88162	0.99886	1.	0.029465
1 atmosphere	=	14.6963	2116.27	1.03325	29.9210	33.9001	33.9388	1.

Table 26—Rate of Flow Equivalents

Units	Cubic feet per second	Cubic feet per minute	U. S. gallons per minute	U. S. gallons per 24 hours	British Imperial gallons per minute	Liters per minute	Acre-feet per hour	Acre-feet per 24 hours
1 cubic foot per second =	1.	60.	448.831	646 317.	373.729	1698.98	0.082645	1.98347
1 cubic foot per minute =	0.016667	1.	7.48052	10 771.9	6.22882	28.3163	0.0013774	0.033058
1 U. S. gallon per minute =	0.0022280	0.13368	1.	1440.	0.83267	3.78533	0.0001841	0.0044192
1 U. S. gallon per 24 hours =	1.547×10^{-6}	9.283×10^{-5}	0.0006944	1.	0.0005782	0.0026287	1.279×10^{-7}	3.069×10^{-6}
1 British Imperial gallon per minute =	0.0026757	0.16054	1.20095	1729.37	1.	4.54601	0.0002211	0.0053072
1 liter per minute =	0.0005886	0.035315	0.26418	380.416	0.21997	1.	4.864×10^{-5}	0.001167
1 acre-foot per hour =	12.1	726.	5430.86	7 820 434.	4522.13	20 557.6	1.	24.
1 acre-foot per 24 hours =	0.50417	30.25	226.286	325 851.	188.422	856.567	0.041667	1.

Table 26—Volume and Capacity Equivalents

Units	United States gallons	British Imperial gallons	Liters	Cubic feet	Cubic inches	Acre-feet
1 United States gallon =	1.	0.832672	3.78533	0.133681	231.	3.069×10^{-6}
1 British Imperial gallon =	1.20095	1.	4.54601	0.160544	277.420	3.686×10^{-6}
1 liter =	0.264177	0.219973	1.	0.035315	61.0250	8.107×10^{-7}
1 cubic foot =	7.48052	6.22882	28.3163	1.	1728.	2.296×10^{-5}
1 cubic inch =	4.329×10^{-3}	3.605×10^{-3}	0.016387	5.787×10^{-4}	1.	1.329×10^{-8}
1 acre-foot =	325 851.	271 328.	1 233 456.	43 560.	75 271 680.	1.
1 inch deep on 1 acre =	27 154.3	22 610.6	102 788.	3 630.	6 272 640.	0.083333
1 inch deep on 1 square mile =	17 378 743.	14 470 801.	65 784 344.	2 323 200.	4 014 489 600.	53.3333
1 meter deep on 1 hectare =	2 641 705.	2 199 675.	9 999 734.	353 145.	610 233 780.	8.10708
1 centimeter deep on 1 square meter =	2.64171	2.19967	9.99973	0.353145	610.234	8.107×10^{-4}
1 pound of water at 39.2° F. =	0.11983	0.099778	0.45359	0.016019	27.6805	3.677×10^{-7}
1 pound of water at 50° F. =	0.11986	0.099806	0.45372	0.016023	27.6880	3.678×10^{-7}
1 pound of water at 62° F. =	0.11997	0.099892	0.45411	0.016037	27.7121	3.682×10^{-7}
1 U. S. gallon per minute for 24 hours =	1440.	1199.05	5450.88	192.5	332 640.	0.0044192
1 cubic foot per minute for 24 hours =	10 771.9	8 969.50	40 775.4	1440.	2 488 320.	0.033058

The pressure head is given by the expression:

$$h_p = \frac{P}{w}$$

where h_p = Pressure head in feet.
P = Pressure in pounds per square foot.

The potential head or head due to height above the datum plane is h_e feet.

The total head, H, is therefore:

$$H = h_v + h_p + h_e$$

or

$$H = \frac{v_1}{2g} + \frac{P}{w} + h_e$$

In any stream flowing steadily without friction, the total head, and the total amount of energy per unit of water, is the same at every point in the path of flow. This principle, which is in reality the law of conservation of energy applied to flowing water, is known as Bernoulli's Theorem.

Table 22 gives the horse power for one cubic foot of water per second, under heads of 1 to 2000 feet, based on an efficiency of 80 per cent. The method of using this table is illustrated by the following example:

Determine the horse power which can be developed by a flow of 60 cubic feet per second under a head of 200 feet.

From the table the horse power for a discharge of one cubic foot per second under 200 feet head is found to be 18.1555. The horse power for a discharge of 60 cubic feet per second under 200 feet head is then:

$$60 \times 18.1555 = 1089.33 \text{ horse power.}$$

When the exact head is not given in the table the horse power may be found by multiplying the horse power for one foot head and one cubic foot per second (0.0907776) by the head in feet and then by the discharge in cubic feet per second. For example, the horse power which can be developed by a discharge of 45 cubic feet per second under a head of 105 feet will be:

$$0.0907776 \times 105 \times 45 = 428.92 \text{ horse power.}$$

Metric Conversion Table

Millimeters × .03937 = inches.
Millimeters ÷ 25.4 = inches.
Centimeters × .3937 = inches.
Centimeters ÷ 2.54 = inches.
Meters × 39.37 = inches (Act of Congress).
Meters × 3.281 = feet.
Meters × 1.094 = yards.
Kilometers × .621 = miles.
Kilometers ÷ 1.6093 = miles.
Kilometers × 3280.8693 = feet.
Square Millimeters × .00155 = sq. inches.
Square Millimeters ÷ 645.1 = sq. inches.
Square Centimeters × .155 = sq. inches.
Square Centimeters ÷ 6.451 = sq. inches.
Square Meters × 10.764 = sq. feet.
Square Kilometers × 247.1 = acres.
Hectare × 2.471 = acres.
Cubic Centimeters ÷ 16.383 = cubic inches.

Cubic Centimeters ÷ 3.69 = fl. drams (U. S. P.).
Cubic Centimeters ÷ 29.57 = fluid ounces (U.S.P.).
Cubic Meters × 35.315 = cubic feet.
Cubic Meters × 1.308 = cubic yards.
Cubic Meters × 264.2 = gallons (231. cubic inches).
Liters × 61.022 = cu. in. (Act of Congress).
Liters × 33.84 = fluid ounces (U. S. P.)
Liters × .2642 = gallons (231. cu. in.).
Liters ÷ 3.78 = gallons (231. cu. in.).
Liters ÷ 28.316 = cubic feet.
Hectoliters × 3.531 = cubic feet.
Hectoliters × 2.84 = bushels (2150.42 cu. in.).
Hectoliters × .131 = cubic yards.
Hectoliters ÷ 26.42 = gallons (231. cu. in.).
Grams × 15.432 = grains (Act of Congress).
Grams ÷ 981. = dynes.
Grams (water) ÷ 29.57 = fluid ounces.
Grams ÷ 28.35 = ounces avoirdupois.

Grams per Cu. Cent. ÷ 27.7 = lbs. per cubic inch.
Joule × .7373 = foot pounds.
Kilograms × 2.2046 = pounds.
Kilograms × 35.3 = oz. avoirdupois.
Kilograms ÷ 907.2 = tons (2,000 lbs.)
Kilograms per Sq. Cent. × 14.223 = lbs. per sq. in.
Kilogram-meters × 7.233 = foot lbs.
Kilograms per Meter × .672 = lbs. per foot.
Kilograms per Cu. Meter × .062 = lbs. per cubic foot.
Tonneau × 1.1023 = tons (2,000 lbs.).
Kilowatts × 1.34 = Horse Power.
Watts ÷ 746. = Horse Power.
Watts × .7373 = foot pounds per second.
Calorie × 3.968 = B.t.u.
Cheval vapeur ÷ .9863 = Horse Power.
(Centigrade × 1.8) + 32 = degrees Fahr.
Gravity Paris = 980.94 centimeters per sec.

LOSS OF HEAD IN PIPES AND FITTINGS†

THERE are numerous times when a water works engineer wishes to know the loss in head in some particular line. Information on this subject is not lacking but often is scattered in various texts and magazines. Diagramatic charts, prepared by the application of the Hazen-Williams, and Scobey formulas for flow of water in pipes have been developed as aids to the solution of problems involving loss of head. Tables and charts of loss of head through valves and fittings are likewise available from various sources and authors.

In an attempt to bring these data tables, charts, and diagrams together in one place the following collection is presented. Together with such running comment as is necessary, the information in the following pages should be sufficient to solve any problem in loss of head.

Flow of Water in Pipe**

The carrying capacity of a pipe line may be regarded as the index of its hydraulic efficiency. Selection of the most suitable hydraulic characteristics to satisfy the economics of a given installation usually involves consideration of several alternate procedures, and comparisons of their respective characteristics, before the most appropriate choice can be made. These comparisons can only be as valid as the underlying hydraulic assumptions they depend on, hence the importance of suitable expressions correctly formulating the proper relationships involved.

Many studies have been made to determine these relationships, and many formulae developed to express them. In 1775, Chezy, a French engineer, offered his well-known formula for the flow of water in open channels and closed conduits:

$$V = C\sqrt{r\,s},$$

"C" being a coefficient at first supposed to have a constant value, but now known to vary with the velocity, slope, hydraulic radius, and with some factor representing influences of contact surfaces. The Kutter elaboration of the Chezy formula reads:

$$V = \left\{ \frac{\dfrac{1.811}{n} + \dfrac{0.00281}{s} + 41.66}{1 + \dfrac{n}{\sqrt{r}}\left(41.66 + \dfrac{0.00281}{s}\right)} \right\} \sqrt{r\,s},$$

in which "C" of the Chezy formula has been developed into the bracketed expression shown at left, which also introduces a new variable "n", supposed to represent all retarding influences. Unfortunately, however, the value of "n" varies somewhat for pipe, both with size and velocity. Now if we examine for a moment the basic formula

$$h_f = \frac{f\,L\,V^2}{2gd}$$

which can be established by the usual hydraulic reasoning, we find the Chezy formula recognizable in it, and also the well-known formula of Darcy, Weisbach and Fanning. All these suffer in a basic respect, in that the friction "constant" does not remain constant throughout the range of application. In the early 1900's these discrepancies began to create a definite reaction against the use of the basic simple assumption that $V = C\sqrt{r\,s}$*, culminating in the presentation of the Williams-Hazen formula. In other words, more critical scrutiny and application of available data indicated that the loss of head does not vary as the square of the velocity, but in accordance with a value lying somewhere between 1.70 and 2.00. It is now fairly well understood that theirs (i. e., the exponential type of formula) is preferable to any other form; also that losses within most closed conduits at velocities within the range of ordinary extremes of service require what Scobey calls "a compromise value somewhat less than 2.00".

The Williams-Hazen formula is now widely accepted, and reads:

$$V = C\,r^{0.63}\,g^{0.54}\,.001^{-0.04}, \text{ where}$$

V = mean velocity of flow, in feet per second.
C = "coefficient of retardation," so-called.
r = mean hydraulic radius of the pipe, or diameter D ÷ 4, in
s = hydraulic grade or slope, in feet per foot of length of a pipe of uniform size.

or

$$s^{0.54} = \frac{V}{C\left(\frac{D}{4}\right)^{0.63}\,.001^{-0.04}}$$

$$= \frac{4^{0.63}\,V}{1.318\,C\,D^{0.63}}$$

$$s = \frac{4^{1.167}\,V^{1.852}}{1.318^{1.852}\,C^{1.852}\,D^{1.167}}$$

$$= \frac{3.0236\,V^{1.852}}{C^{1.852}\,D^{1.167}}$$

$$s_{1000}\left\{\begin{matrix}\text{Loss of Head}\\ \text{in Feet, per}\\ \text{1,000 Feet}\end{matrix}\right\} = \frac{3023.6\,V^{1.852}}{C^{1.852}\,D^{1.167}} = K\frac{V^{1.852}}{D^{1.167}}$$

when

C =	90	95	100	105	110	115	120	125	130	135	140
K =	.727	.657	.598	.546	.501	.461	.426	.395	.367	.343	.321

Loss of Head Charts Based on the Hazen-Williams and Scobey Formulas

In the following pages appear four charts for determining loss of head in lineal pipe lines. The first three were developed from the Hazen-Williams Formula and apply to any pipe. The last was developed from the Scobey formula and is applicable to concrete pipes.

The first of these charts was prepared by William P. Creager, Chief Engineer, The Power Corporation of New York, and was originally published by John Wiley and Sons in Hydro-Electric Handbook, by Creager and Justin.

The second and third of these charts are nomographs and were prepared for an article on the Hardy Cross Method by D. R. Taylor (WATER WORKS AND SEWERAGE, March 1943). The last chart, also a nomograph, was prepared by J. R. Griffiths, of the U. S. Navy, and first appeared in *Western Construction News.*

Values of the Coefficient "C"

Although the second and third charts are for definite values of the friction coefficient "C" in the Hazen-Williams Formula, the first chart by Creager may be used for any value of "C," if that value is known.

Recommended values of "C" for the Hazen-Williams Formula were given by Hazen and Williams in their book, "Hydraulic Tables" published by John Wiley and Sons, in 1920. These values for straight line conduits are shown in the following tables.

TABLE I—TABLE OF C VALUES
CAST IRON PIPE

Diameter Inches	Age in Years* 0	5	10	20	30	40	50
4	130	118	107	89	75	64	55
8	130	119	109	93	83	73	65
12	130	120	111	96	86	77	70
16	130	120	112	98	87	80	72
24	130	120	113	100	89	81	74
30	130	120	113	100	90	83	76
36	130	120	113	100	90	83	76
40	130	120	113	100	90	83	77
60	130	120	113	100	90	83	77

*Cleaning old pipe increases the C value.

Riveted Steel Pipe
- Light riveted steel pipe—Avg. C for any age = 10 year C.I.P.
- Heavy riveted steel pipe—Avg. C for any age = 20 year C.I.P.

Welded Steel Pipe
- Equivalent to 5 yr. or older C.I.P.

Wood Stave Pipe
- Best C = 145
- Probable Average C = 120
- Worst C = 110

Concrete Pipes and Pressure Tunnels

Metal Forms
- Best workmanship— C = 150
- Probable workmanship—C = 140
- Worst workmanship— C = 120

Wood Form—Monolithic
- Best workmanship— C = 130
- Probable workmanship—C = 120
- Worst workmanship— C = 90

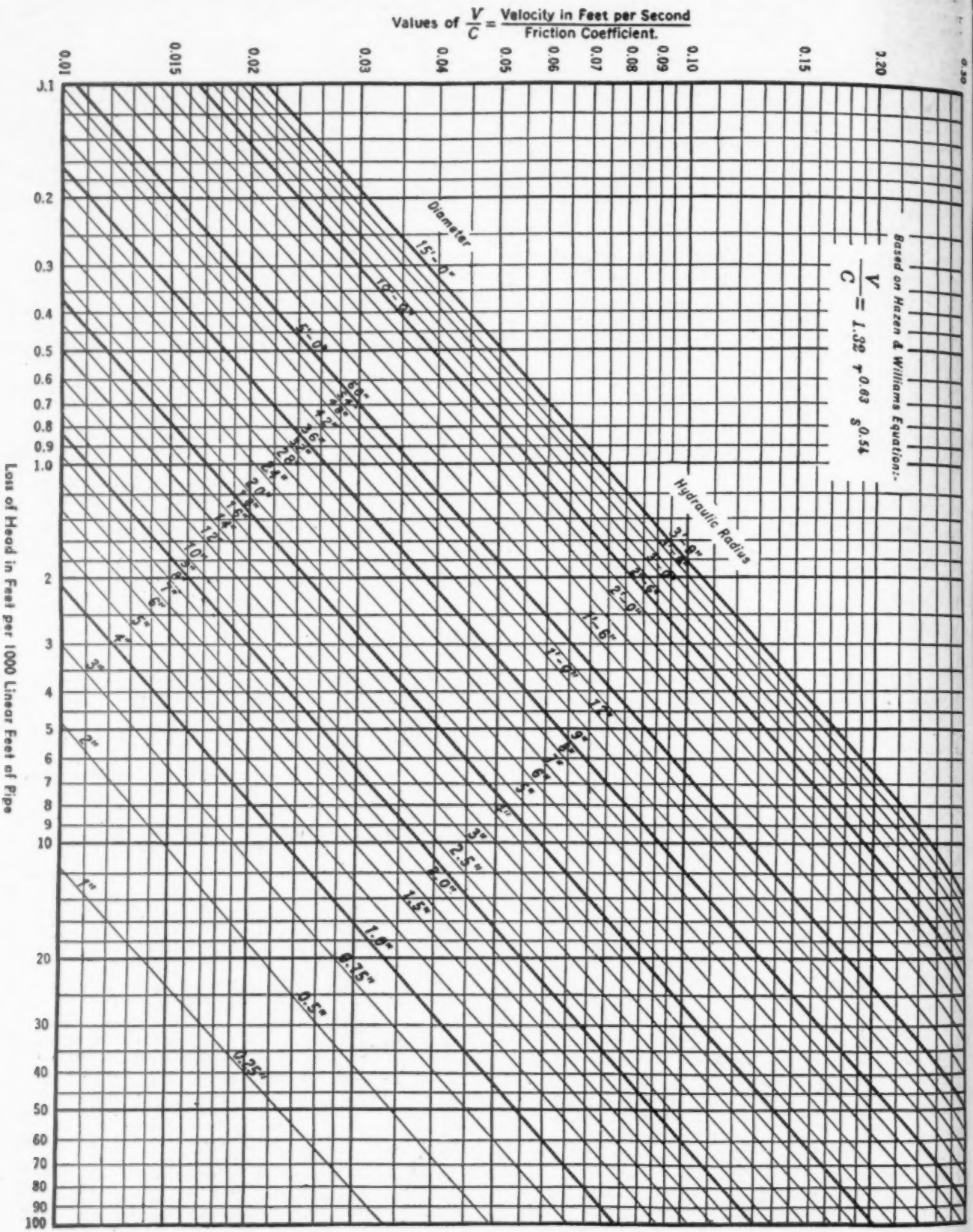
If Slimed
- 20 points below Best
- 15 points below Average
- 10 points below Worst

†Prepared from material gathered from the various sources credited in the text.

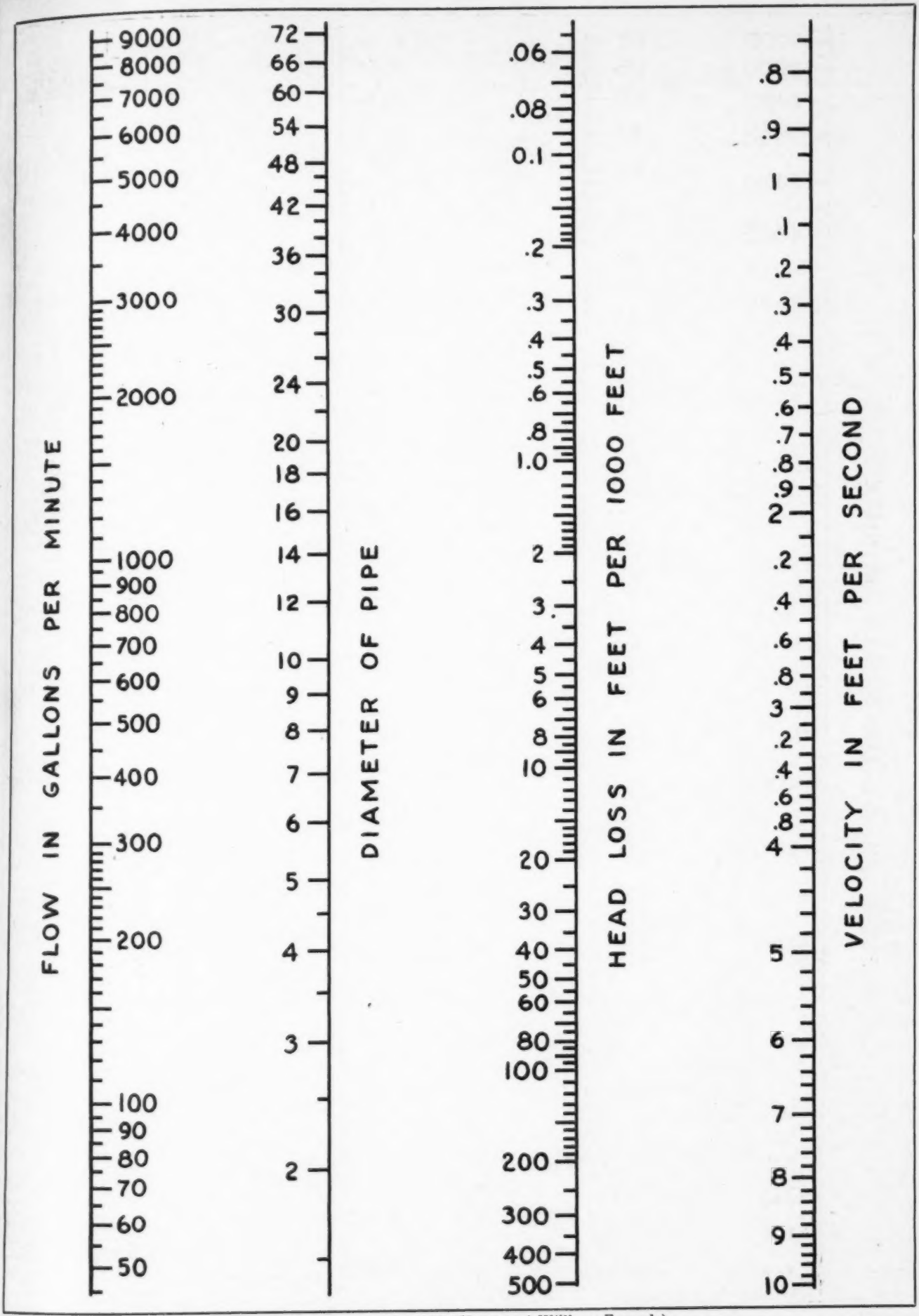
*Convertible into the general formula $H = k\frac{Vx}{D^y}$; when H = 1000s, x = 2, and y = 1.

**From Cat. No. 404, Taylor Forge and Pipe Works.

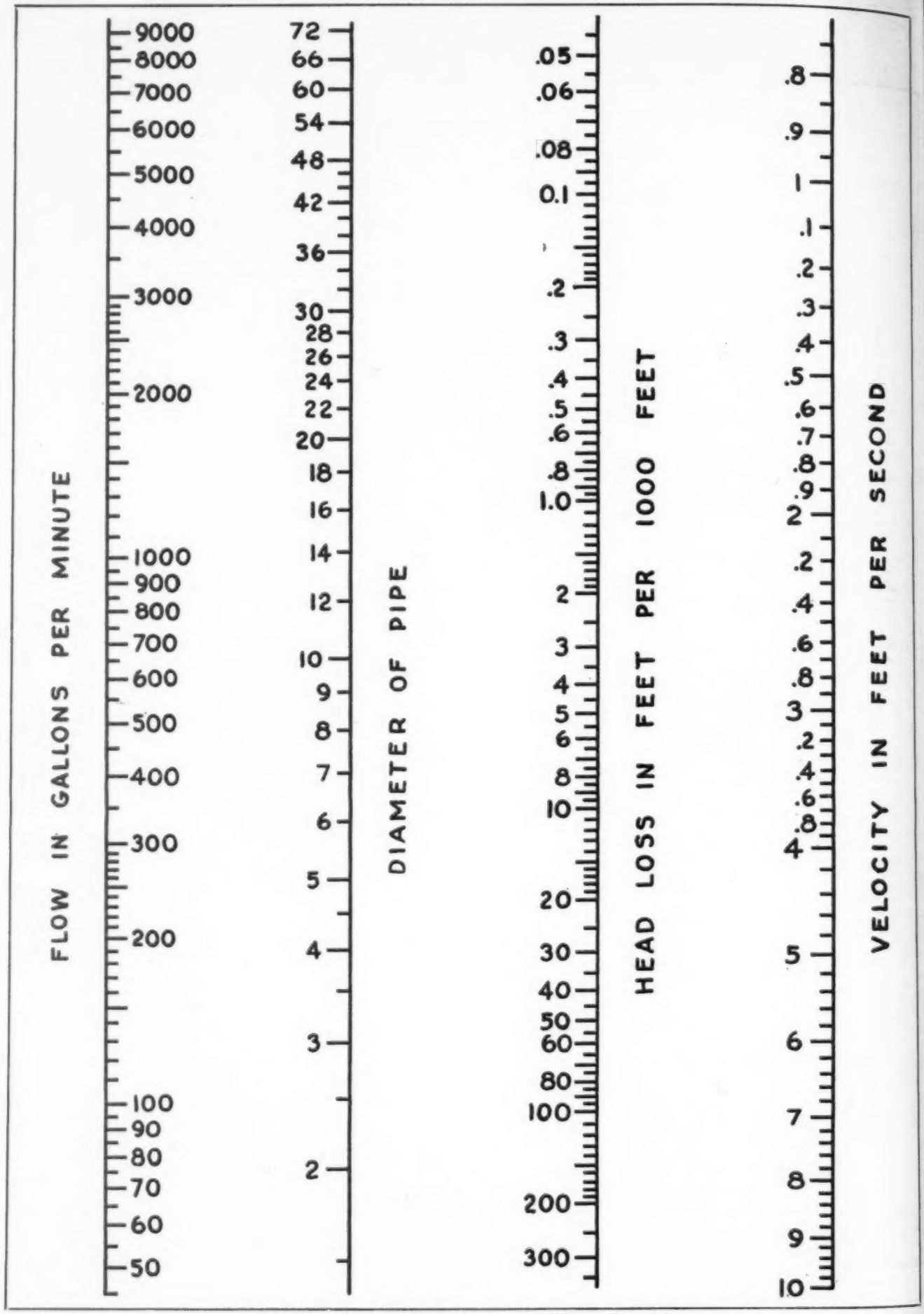
CHART OF LOSS OF HEAD IN FEET PER 1000 FT. OF PIPE



From "Hydro-Electric Handbook"—John Wiley & Sons

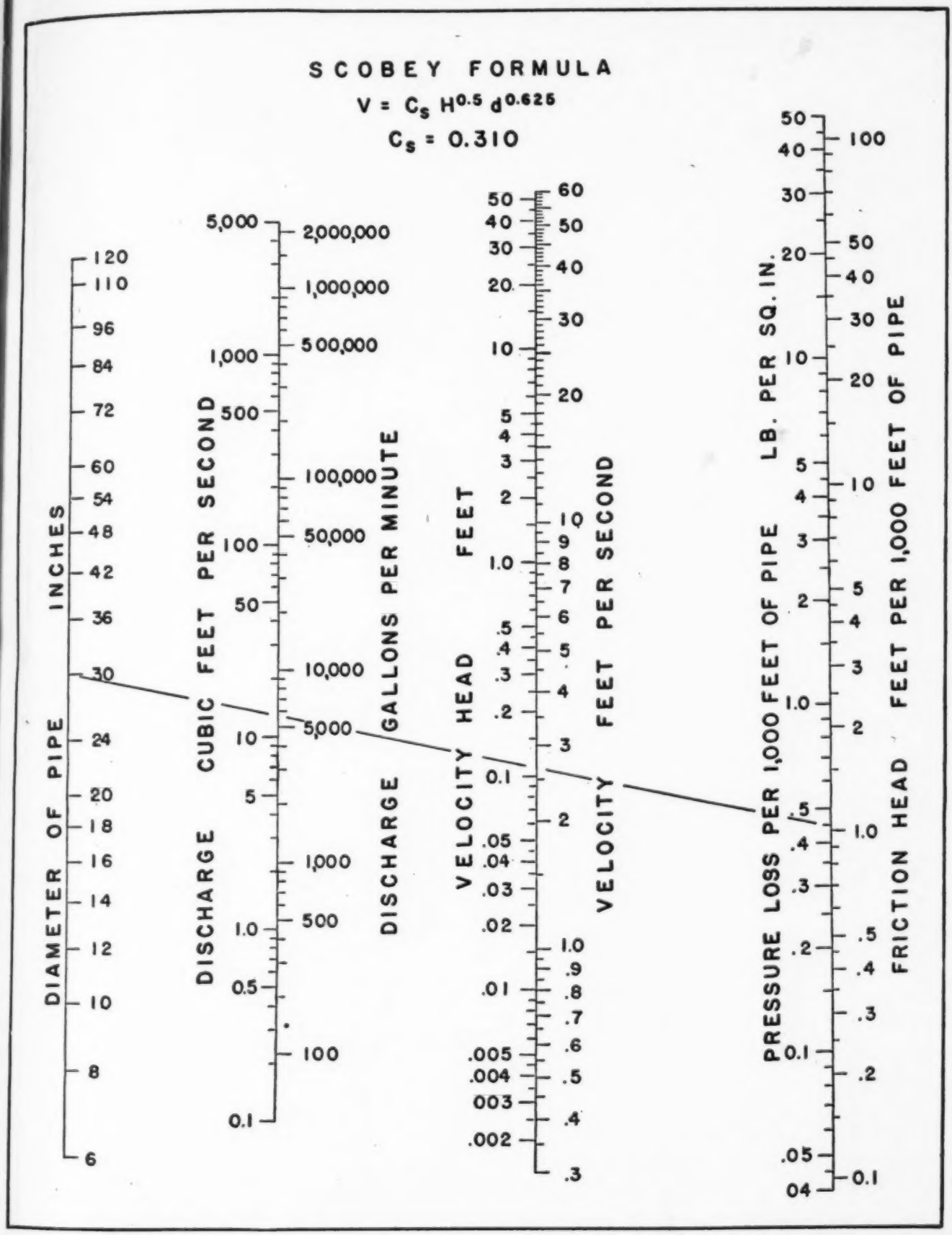


Flow Chart for C = 100 (Hazen and Williams Formula)



Flow Chart for C = 120 (Hazen and Williams Formula)

FLOW OF WATER IN CONCRETE PIPE


SCOBEY FORMULA
V = $C_s H^{0.5} d^{0.625}$
C_s = 0.310
DIAMETER OF PIPE INCHES
DISCHARGE CUBIC FEET PER SECOND
DISCHARGE GALLONS PER MINUTE
VELOCITY HEAD FEET
VELOCITY FEET PER SECOND
PRESSURE LOSS PER 1,000 FEET OF PIPE LB. PER SQ. IN.
FRICTION HEAD FEET PER 1,000 FEET OF PIPE

Courtesy of J. R. Griffith, U. S. Navy, and Western Construction News.

In addition to the values in the above table the following values of the friction coefficient have been published by the National Tube Company in Technical Bulletin No. 21.

These values of the coefficient "C" are to be used in the Hazen-Williams formula for computing the loss of head due to friction in new well-laid pipe:

Kind of Pipe	Coefficient	Kind of Pipe	Coefficient
"Duroline"	148*†	Wood Stave	120
Wrought Steel	140	Riveted Steel	110
Small Brass and Copper	130	Vitrified Pipe	110
Cast Iron	130	Brick Sewers	100
Concrete	120		

*"Duroline" pipe is protected against internal corrosion and mounting friction losses by a cement base composition lining of a highly durable nature.—Ed.

†Approximately the same for cement lined pipe.—Ed.

It must be understood that these values depend upon the smoothness and regularity of the surfaces and are likely to vary in individual cases. In designing a pipe line it is customary to use somewhat lower coefficients than those above, to allow for variations due to local conditions, and for reduction of carrying capacity with age due to roughening of the inside surface, accumulation of corrosion products, and tuberculation. However, in case of cement or enamel lined pipe, the volume of flow remains practically unchanged over long periods of service due to the fact that rust tubercles do not form and the initially smooth inside surface is retained.

Useful Loss of Head Tables

D. R. Taylor in his article in Water Works and Sewerage (Mar. 1943) gives two tables on loss of head. The first (table II) gives values for use in the formula

$$S = r\,Q_m^{1.85}$$

where S = loss of head per 1000 ft.
r = resistance factor depending on size and smoothness of pipe.
Q_m = quantity of flow in gal. per min.

Values in the table are given as "k" values which are equal to 100,000 times the "r" value.

TABLE II

Values of k for 1,000 Feet of Pipe Based on the Hazen-Williams Formula

Pipe Diameter, Inches / C =	90	100	110	120	130	140
4	300	248	208	117	153	133
6	41	33.7	28.4	24.2	20.9	18.2
8	10	8.4	7.0	6.0	5.2	4.5
10	3.4	2.8	2.4	2.0	1.7	1.5
12	1.5	1.2	1.0	.83	.71	.62
14	.66	.55	.46	.39	.34	.30
16	.35	.29	.24	.20	.18	.15
18	.20	.16	.14	.12	.10	.09
20	.12	.10	.08	.07	.06	.05
24	.049	.04	.03	.03	.02	.02
30	.016	.013	.011	.010	.008	.007
36	.0067	.0054	.0046	.0039	.0034	.0030

Table III gives "r" values when the flow quantity is expressed in mil. gal. per day, for the formula $S = rQ_x^{1.85}$
where s = loss of head per 1000 ft. of pipe.
r = resistance factor
Q_x = quantity flow in m.g.d.

In Table IV are listed pipe friction for various size pipes and velocities. This table is taken from a Layne-Bowler Pump Bulletin.

Loss of Head for Valves and Fittings

The following discussion and its accompanying chart titled Friction Chart for Valves and Fittings have been taken from Crane Company's "Engineering Data on Flow of Fluids in Pipes —Tech. Bull. No. 405, 1935."

When the flow of a fluid in a pipe line is altered by some obstruction such as a valve or fitting, the velocity is changed, turbulence is magnified and a drop in pressure results. This pressure drop may be insignificant in long lines where it is very small in comparison to the total drop, but when the line is short the pressure drop through valves and fittings becomes a major item in the total pressure drop value.

The most widely used data on the subject of the resistance of valves and fittings to the flow of water and steam is the information given in Dean Foster's paper on "Effect of Fittings on Flow of Fluids Through Pipe Lines" published in Vol. 42, 1920, of the Transactions of the American Society of Mechanical Engineers. Recently, tests conducted by others have indicated that the values given by Foster are low for globe valves, angle valves, etc., and that data is needed to establish the correct information to use. It has been the tendency, and probably is the most practical way, to present the friction values in terms of an equivalent length of the same size of pipe; i.e., the pressure drop caused by a 2-inch elbow is equivalent to approximately the pressure drop caused by five or six feet of 2-inch pipe under the same conditions of flow.

Realizing the need for definite data covering this subject, Crane Co. has recently conducted pressure drop tests on valves and fittings on both water and steam. These tests were made on 2 inch and 6 inch sizes and conducted under conditions which were thoroughly investigated previous to the tests. The results of these tests are presented herewith together with a description of the method used in conducting them.

[*Note.*—Water and steam can be treated comparatively and a relation can be established between the relative friction values of water and steam. Foster has stated that the equivalent length of pipe for steam flow is about .8 of that established for the flow of water.]

Friction Losses of Water Line Valves and Fittings

The tests for determining the pressure drop of valves and fittings installed in a water line were made in the following manner:

A flow nozzle was installed in a 3 in. test line leading from the bottom of a 1,000 gallon water tank. A mercury manometer was set across this nozzle and the relation of mercury deflection to the gallons of water per minute flowing through the pipe was determined. The flow through the pipe was thereafter noted only in terms of mercury deflection which was readily transposed into gallons per minute by reference to the calibration chart.

The valve or fitting to be tested was placed in the line at some distance from the flow nozzle and the flow water through it was regulated by a throttling valve situated at the outlet of the line. The pressure drop was measured by means of a mercury manometer, or where the deflection was too great, by two sensitive low pressure gages, the leads of which were situated in the test line at a distance of ten pipe diameters (20 in.)

TABLE III

VALUES OF "R" FOR 1,000 FT. OF PIPE BASED ON HAZEN AND WILLIAMS FORMULA

Head Loss in Ft.: $S = r \times Q^{1.85}$ per 1,000 ft. (Q in M.G.D.)

d—Inches	c = 70	c = 80	c = 90	c = 100	c = 110	c = 120	c = 130	c = 140
4	860.69	672.31	540.67	444.91	373.00	317.53	273.83	238.76
6	119.44	93.30	75.03	61.74	51.76	44.06	38.00	33.13
8	29.42	22.98	18.48	15.21	12.75	10.85	9.36	8.16
10	9.93	7.75	6.24	5.13	4.30	3.66	3.16	2.75
12	4.08	3.19	2.57	2.11	1.77	1.51	1.30	1.13
14	1.925	1.504	1.209	0.995	0.834	0.710	0.612	0.534
16	1.007	0.787	0.633	0.521	0.437	0.372	0.320	0.279
18	0.567	0.443	0.356	0.293	0.246	0.209	0.180	0.157
20	0.3390	0.2648	0.2130	0.1753	0.1469	0.1251	0.1079	0.0941
24	0.1396	0.1091	0.0877	0.0722	0.0605	0.0515	0.0444	0.0378
30	0.0471	0.0368	0.0296	0.0244	0.0204	0.0174	0.0150	0.0151
36	0.01939	0.01514	0.01218	0.01002	0.00840	0.00715	0.00617	0.00528
42	0.00915	0.00715	0.00575	0.00473	0.00397	0.00338	0.00291	0.00254
48	0.004774	0.003729	0.002999	0.002468	0.002057	0.001761	0.001519	0.001324
60	0.001611	0.001258	0.001012	0.000833	0.000698	0.000594	0.000513	0.000447
66	0.001013	0.000791	0.000636	0.000524	0.000439	0.000374	0.000322	0.000281

TABLE IV

Friction of Water in Pipes

The pipe frictions shown in the following tables are taken by permission from the more complete copyright tables by Williams and Hazen, published by John Wiley & Sons, and these values are recommended for use in figuring pipe frictions.

Loss of Head in Feet Due to Friction, per 100 feet of 15 year old Ordinary Iron Pipe

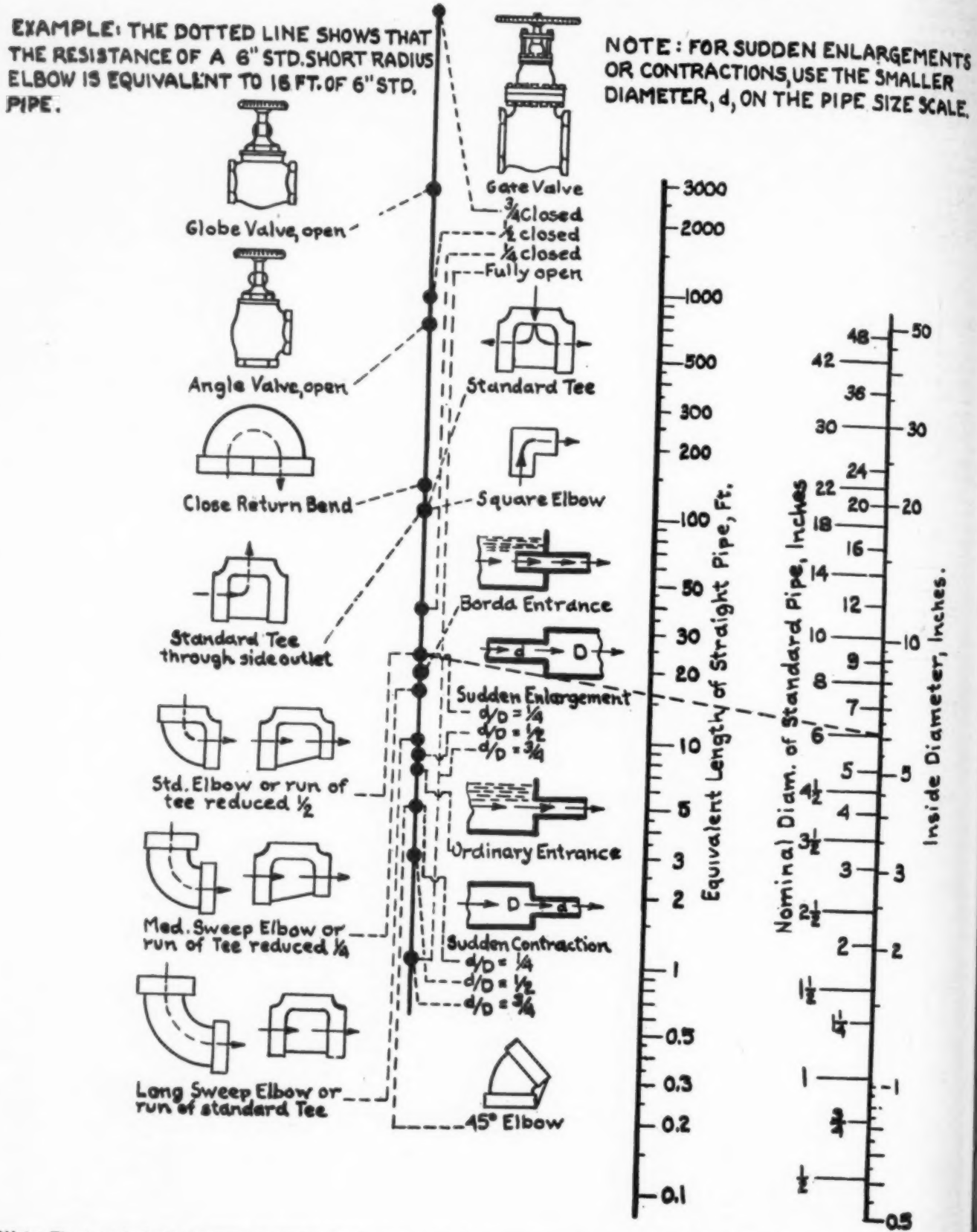
U.S. Gal's per Min.	1" Pipe		1¼" Pipe		1½" Pipe		2" Pipe		2½" Pipe		3" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
10	3.72	11.7	2.14	3.05	1.57	1.43	1.02	0.50	0.65	0.17	0.45	0.07
15	5.60	25.0	3.2	6.50	2.36	3.0	1.53	1.0	0.98	0.36	0.68	0.15
20	7.44	42.0	4.29	11.1	3.15	5.2	2.04	1.82	1.31	0.61	0.91	0.25
25	9.30	64.0	5.36	16.6	3.94	7.8	2.55	2.73	1.63	0.92	1.13	0.38
30	11.15	89.0	6.43	23.5	4.72	11.0	3.06	3.84	1.96	1.29	1.36	0.54
35	13.02	119.0	7.51	31.2	5.51	14.7	3.57	5.1	2.29	1.72	1.59	0.71
40	14.88	152.0	8.58	40.0	6.3	18.8	4.08	6.6	2.61	2.20	1.82	0.91
45	.....	.....	9.65	50	7.08	23.2	4.60	8.2	2.94	2.80	2.05	1.15
50	.....	.....	10.72	60	7.87	28.4	5.11	9.9	3.27	3.32	2.27	1.38
70	.....	.....	15.01	113	11.02	53.0	7.15	18.4	4.58	6.2	3.18	2.57
90	.....	.....	.....	.....	14.17	84.0	9.19	29.4	5.88	9.8	4.09	4.08
100	.....	.....	.....	.....	15.74	102.0	10.21	35.8	6.54	12.0	4.54	4.96
120	.....	.....	.....	.....	18.89	143.0	12.25	50.0	7.84	16.8	5.45	7.0
140	.....	.....	.....	.....	22.04	190.0	14.30	67.0	9.15	22.3	6.35	9.2
160	.....	.....	.....	.....	.....	.....	16.34	86.0	10.46	29.0	7.26	11.8
180	.....	.....	.....	.....	.....	.....	18.38	107.0	11.76	35.7	8.17	14.8
200	.....	.....	.....	.....	.....	.....	20.42	129.0	13.07	43.1	9.08	17.8
220	.....	.....	.....	.....	.....	.....	22.47	154.0	14.38	52.0	9.99	21.3
240	.....	.....	.....	.....	.....	.....	24.51	182.0	15.69	61.0	10.89	25.1
260	.....	.....	.....	.....	.....	.....	26.55	211.0	16.99	70.0	11.80	29.1
280	.....	.....	.....	.....	.....	.....	.....	.....	18.30	81.0	12.71	33.4
300	.....	.....	.....	.....	.....	.....	.....	.....	19.61	92.0	13.62	38.0

U. S. Gal's per Min.	4" Pipe		5" Pipe		6" Pipe		8" Pipe		10" Pipe		12" Pipe		14" Pipe		15" Pipe		16" Pipe		20" Pipe		24" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
40	1.02	0.22	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
45	1.17	0.28	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
50	1.28	0.34	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
70	1.79	0.63	1.14	0.21	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
75	1.92	0.73	1.22	0.24	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
100	2.55	1.22	1.63	0.41	1.14	0.14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
120	3.06	1.71	1.96	0.58	1.42	0.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
125	3.19	1.86	2.04	0.64	1.48	0.28	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
150	3.84	2.55	2.45	0.88	1.71	0.32	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
175	4.45	3.44	2.86	1.18	2.00	0.48	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
200	5.11	4.40	3.27	1.48	2.28	0.62	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
225	5.77	5.45	3.67	1.86	2.57	0.74	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
250	6.40	6.72	4.08	2.24	2.80	0.92	1.60	0.22	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
270	6.90	7.70	4.42	2.60	3.03	1.13	1.70	0.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
275	7.03	7.99	4.50	2.72	3.06	1.15	1.73	0.27	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
300	7.66	9.30	4.90	3.14	3.40	1.29	1.90	0.32	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
350	8.90	12.32	5.72	4.19	3.98	1.75	2.20	0.42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
400	10.21	16.00	6.54	5.40	4.54	2.21	2.60	0.54	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
450	11.50	19.80	7.35	6.70	5.12	2.65	2.92	0.68	1.80	0.21	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
470	12.10	22.40	7.70	7.22	5.49	2.90	3.07	0.75	1.92	0.24	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
475	12.20	22.96	7.76	7.42	5.55	2.95	3.10	0.76	1.94	0.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
500	12.77	24.00	8.17	8.12	5.60	3.30	3.20	0.82	2.04	0.28	1.42	0.11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
550	.....	.....	8.99	9.60	6.16	3.93	3.52	0.97	2.25	0.33	1.57	0.14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
600	.....	.....	9.80	11.30	6.72	4.70	3.84	1.14	2.46	0.39	1.71	0.15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
650	.....	.....	10.62	13.20	7.28	5.40	4.16	1.34	2.66	0.46	1.85	0.19	1.37	0.09	.....	.....	.....	.....	.....	.....	.....	.....
700	.....	.....	11.44	15.10	7.84	6.20	4.46	1.54	2.86	0.52	2.00	0.22	1.47	0.10	.....	.....	.....	.....	.....	.....	.....	.....
750	.....	.....	12.26	17.20	8.50	7.00	4.80	1.74	3.06	0.59	2.13	0.24	1.58	0.11	.....	.....	.....	.....	.....	.....	.....	.....
800	.....	.....	.....	.....	9.08	8.00	5.12	1.97	3.28	0.67	2.27	0.27	1.68	0.13	.....	.....	.....	.....	.....	.....	.....	.....
850	.....	.....	.....	.....	9.58	8.95	5.48	2.28	3.48	0.75	2.41	0.31	1.79	0.14	.....	.....	.....	.....	.....	.....	.....	.....
900	.....	.....	.....	.....	10.30	10.11	5.75	2.46	3.68	0.83	2.56	0.34	1.89	0.16	.....	.....	.....	.....	.....	.....	.....	.....
950	.....	.....	.....	.....	10.72	10.80	6.06	2.87	3.88	0.91	2.70	0.38	2.00	0.18	1.73	0.12	.....	.....	.....	.....	.....	.....
1000	.....	.....	.....	.....	11.32	12.04	6.40	3.02	4.08	1.01	2.84	0.41	2.10	0.19	1.82	0.14	.....	.....	.....	.....	.....	.....
1050	.....	.....	.....	.....	11.90	13.30	6.70	3.21	4.29	1.09	2.98	0.44	2.20	0.22	1.91	0.16	.....	.....	.....	.....	.....	.....
1100	.....	.....	.....	.....	12.50	14.31	7.03	3.51	4.50	1.20	3.13	0.49	2.31	0.23	2.00	0.17	.....	.....	.....	.....	.....	.....
1150	.....	.....	.....	.....	12.95	15.60	7.35	3.84	4.71	1.34	3.27	0.53	2.42	0.25	2.09	0.18	.....	.....	.....	.....	.....	.....
1200	.....	.....	.....	.....	13.52	16.69	7.67	4.15	4.91	1.46	3.41	0.57	2.52	0.26	2.18	0.19	.....	.....	.....	.....	.....	.....
1250	.....	.....	.....	.....	14.10	18.50	8.00	4.45	5.11	1.51	3.55	0.62	2.63	0.29	2.28	0.20	1.99	0.15	.....	.....	.....	.....
1500	.....	.....	.....	.....	.....	.....	9.60	6.27	6.10	2.09	4.20	0.85	3.15	0.39	2.73	0.28	2.39	0.21	.....	.....	.....	.....
2000	.....	.....	.....	.....	.....	.....	12.70	10.71	8.10	3.65	5.60	1.43	4.20	0.66	3.64	0.54	3.19	0.39	.....	.....	1.42	0.05
2500	.....	.....	.....	.....	.....	.....	.....	.....	10.10	5.33	7.00	2.28	5.25	1.01	4.55	0.72	3.99	0.56	.....	.....	1.77	0.07
3000	.....	.....	.....	.....	.....	.....	.....	.....	12.10	7.80	8.40	3.15	6.30	1.47	5.46	1.12	4.79	0.80	3.08	0.27	2.13	0.10
3500	.....	.....	.....	.....	.....	.....	.....	.....	14.10	10.08	9.80	4.10	7.35	1.81	6.37	1.43	5.59	1.04	3.59	0.35	2.49	0.14
4000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11.35	5.32	8.40	2.47	7.28	1.85	6.38	1.34	4.10	0.45	2.85	0.18
4200	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11.93	6.00	8.82	2.80	7.64	2.08	6.72	1.45	4.32	0.50	.....	.....
4500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	12.78	6.90	9.45	3.22	8.19	2.23	7.20	1.65	4.62	0.56	3.20	0.22
5000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	14.20	8.40	10.50	3.92	9.10	2.78	7.96	2.02	5.13	0.68	3.54	0.27
5500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11.55	4.65	10.01	3.30	8.78	2.39	5.64	0.82	3.90	0.33
6000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	12.60	5.50	10.92	3.90	9.56	2.60	6.15	0.96	4.25	0.38
6500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13.65	6.45	11.83	4.55	10.36	3.32	6.66	1.06	4.61	0.45
7000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	14.70	7.15	12.74	5.08	11.12	3.68	7.18	1.28	4.97	0.52
7200	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13.10	5.45	11.50	3.96	7.38	1.35	.....	.....
7500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13.65	5.90	11.95	4.28	7.66	1.45	5.32	0.59
8000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8.17	1.63	5.68	0.66
8500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8.68	1.83	6.03	0.74
9000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.20	2.04	6.35	0.81
9500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.70	2.23	6.74	0.91
10000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.40	2.53	7.07	0.98

Vel.—Velocity ft. per second. Fric.—Friction head in feet.

FRICTION CHART FOR VALVES AND FITTINGS

For Converting These Units Into Equivalent Added Length of Pipe*



*Note: These equivalents, in terms of length of pipe to be added in computations, were derived for steel pipe in good condition. In applying the chart to cast-iron pipe divide the equivalent length of steel pipe by 1.64 times the most appropriate age factor found in the accompanying table of "Age Factors" for C.I. mains.

from each end of the valve or fitting on test. The initial pressure at the inlet of the test line was kept constant at 80 pounds per square inch and the various rates of flow produced by throttling the outlet of the test line.

After the data was obtained the means of presenting it in its best form was investigated. In any pressure drop tabulation, the values for the fittings and valves in the line are added to the pressure drop of the entire length of line. Therefore, it seemed reasonable to disregard the pressure drop caused by the length of the valve or fitting and just list the pressure drop which was added to the line due to the presence of the article.

For instance, if a valve 4 in. face to face is installed in a line 30 in. long, the actual pressure drop through the valve will be the total pressure drop minus the pressure drop caused by 26 in. of pipe. However, in a practical problem this value will be added to the pressure drop caused by the total length of the line which will give a pressure drop value slightly higher than the actual. This may not be so noticeable with one or two valves or fittings in the line, but where the number runs up into 10 or 20 the added drop may be considerable.

This "No-length" concept was established and has been used before with reference to elbows in "The Friction of Water in Pipes and Fittings" by F. E. Giesecke, University of Texas Bulletin No. 1759.

Resistance in Terms of Equivalent Pipe Length

From data given in the tests conducted by Crane Co. and also from information gathered from authentic sources, Fig. 16, has been prepared which gives the equivalent length of pipe to produce the same pressure drop as a valve or fitting. This additional pipe length should be added to the length of the line in order to determine the total pressure drop.

The equivalent length of pipe has been based upon the pressure drop values for the flow of water in pipes and upon the following coefficients of

$$H_1 = k\frac{V^2}{2g}$$

H_1 = Loss of head in ft.
k = Coefficient.
V = Vel. in ft. per sec.
$2g$ = 64.4.

Type	Coefficient	Authority
Globe Valves	10	Crane Tests
Angle Valve	5	Crane Tests
Return Bend	2.2	
Tee	1.8	Giesecke & Bladgett—Texas College
Short Radius Elbow.	.9	Giesecke & Bladgett—Texas College
Med. Radius Elbow..	.75	& Crane tests
Long Radius Elbow..	.60	Bulletin No. 2712—U. of Texas
Gate Valve (Open)..	.19	Bulletin No. 252—U. of Wis. (Av.)
¼ Closed	1.15	Bulletin No. 252—U. of Wis. (Av.)
½ Closed	5.6	Bulletin No. 252—U. of Wis. (Av.)
¾ closed	24.0	Bulletin No. 252—U. of Wis. (Av.)
Borda Entrance	.83	"Hydraulic" Daugherty (Average)
Sudden Enlargement		
d/D — ¼	.92	"Hydraulics" Daugherty
d/D — ½	.56	"Hydraulics" Daugherty
d/D — ¾	.19	"Hydraulics" Daugherty
Ordinary Entrance	.5	"Hydraulics" Daugherty
Sudden Contraction		
d/D = ¼	.42	"Hydraulics" Daugherty
d/D = ½	.33	"Hydraulics" Daugherty
d/D = ¾	.19	"Hydraulics" Daugherty
45° Elbow	.42	Bulletin No. 2712—U. of Texas

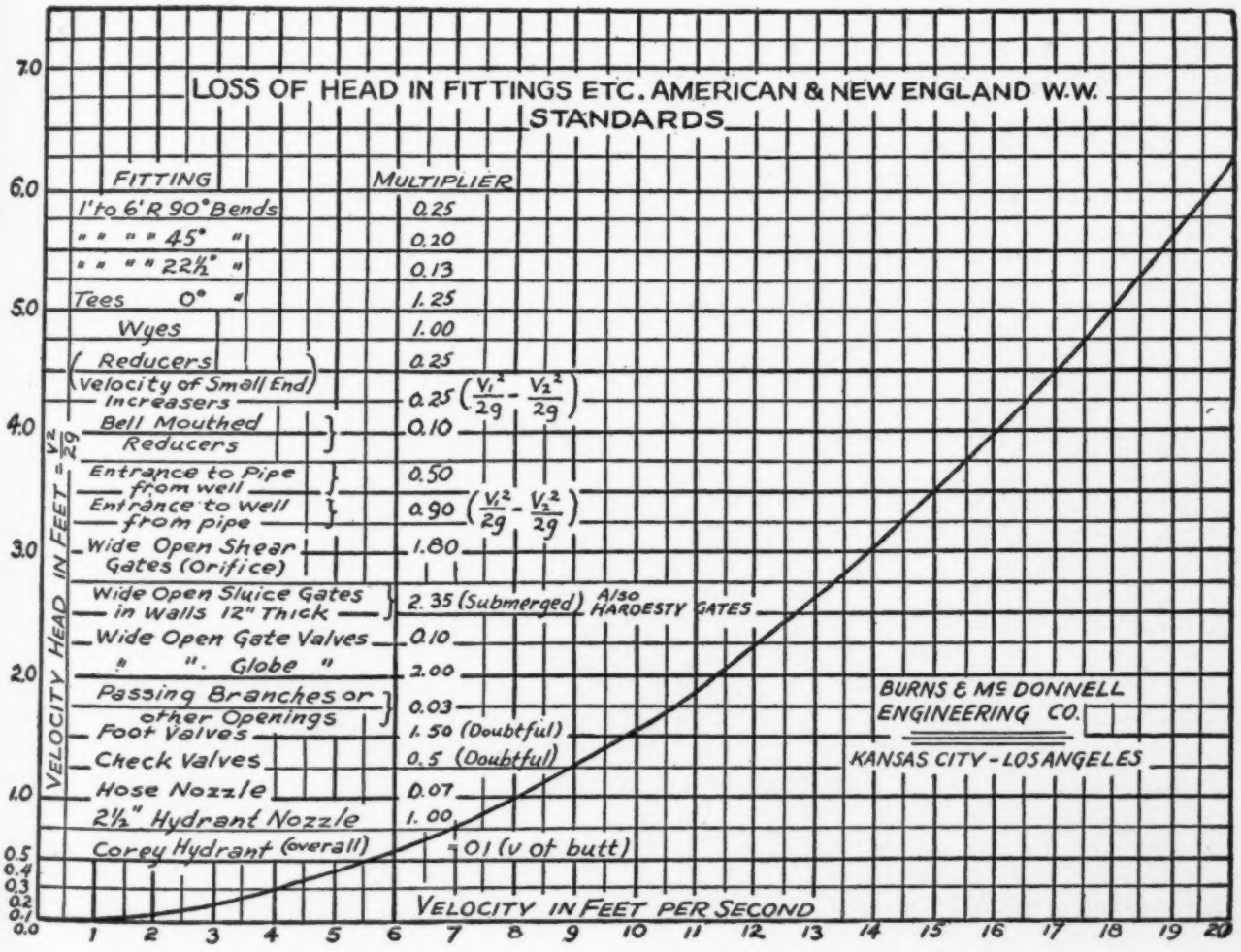
AGE FACTORS

	Age in Years						
	New	10	15	20	30	50	75
Fire Protection Mains							
No Domestic Draft	0.7	0.9	1.0	1.1	1.4	1.8	2.3
Public and Fire Protection Mains with Domestic Draft							
Surface Water							
Slight Tuberculation	0.7	0.9	1.0	1.1	1.4	1.8	2.3
Moderate Tuberculation	0.7	1.2	1.7	2.1	2.9	3.5	3.9
Severe Tuberculation	0.7	1.6	2.4	3.1	4.5	5.2	5.5
Well Water	0.7	1.6	2.4	3.1	4.5	5.2	5.5

These age factors for cast-iron mains are adapted from the results of an investigation by a committee of the New England Water Works Association and reported in their Proceedings, Vol. XLIX, No. 3, September, 1935.

Burns and McDonnell, Engineers, have prepared the following chart to determine loss of head through valves and fittings.

To determine loss of head—Assume flow (Q) to be 5 cu. ft. sec. through a fitting of 12 inch diameter. From Q—AV the



velocity (V) = 6.4 ft. per sec. From the chart, velocity head $\frac{V^2}{2g}$ = 0.7 ft. Applied to 90 degree bend head loss is 0.25 × 0.7 = 0.18 ft. For a tee 1.25 × .7 = 0.87 ft.

(Note—Recent correspondence with the producers of this chart cites values for check valves far in excess of the 0.5 indicated.—*Ed.*)

Another method of determining loss of head in fittings and valves is given in the following table with approximate head losses for various fittings. Exact losses cannot be determined due to variation in construction details.

TABLE OF VALUES

Diameter of fittings	1	1½	2	2½	3	4	5	6	7	Inches
Constant	2.5	3.75	5	6.25	7.5	10	12.5	15	17.5	Constant
	8	9	10	11	12	15	16	18	20	Inches
	20	22.5	25	27.5	30	37.5	40	45	50	Constant

MULTIPLIERS FOR DIFFERENT FITTINGS

45° Ell	0.26	Water Meters:	
90° Ell	1.0	Disk or wobble plate type	9.0
Tee	2.0	Rotary (disk of star shape, as piston)	13.3
*Gate Valve	0.37	Reciprocating piston	20.0
*Globe Valve	3.33	Turbine wheel type (Double flow balanced)	8.3
*Angle Globe Valve	5.0	Venturi Meters:	
*Check Valve	3.0	Ratio of $d_2/d_1 = 0.5$	2.66
		Ratio of $d_2/d_1 = 0.4$	5.06

*Multipliers are for valves operating wide open.

In the TABLE OF VALUES under each size fitting is a constant which, multiplied by the multiplier for each kind of fitting in the pipe line, will give the additional length in feet to be added to the actual length of discharge pipe or pipe line. Take, for example, a 10-inch pipe line 300-feet long with 2-90° ells, 1-gate valve, 1-check valve and a venturi meter having a ratio of $d_2/d_1 = 0.5$. The additional length for head loss in these fittings is made up as follows: 2-90° ells 25-feet each, 1-gate valve 9-feet, 1-check valve 75-feet, 1-venturi meter 66-feet, making a total of 200-feet additional which must be added to the 300-feet actual length, or the equivalent of 500-feet of new 10-inch pipe line upon which the friction head loss must be figured in order to arrive at the total loss in the pipe line and fittings.

TRANSPORTATION SIMPLIFIED

Power Crane-Equipped Truck Makes for Ease and Economy

By D. R. TAYLOR

Plant Superintendent, Water Department, Roanoke, Virginia

THE problem of transportation is one that many of us were confronted with when we began using cast iron pipe 18 feet long. If you have much hauling to do, it will pay you to buy a long wheel-base truck chassis and to have a power crane installed on it and have a platform body built locally to meet your particular needs. Such a truck chassis that we purchased and equipped when we began the use of 18 foot pipe is here pictured. The power crane was obtained from the Baker Equipment Corp., Richmond, Va., who are our nearest agents for the Gar Wood Industries of Detroit.

The truck chassis should have a wheel base of at least 220 inches. The dimensions of our particular piece of equipment are as follows: The length from the back of the cab to the end of the frame is 19 feet. The crane utilizes 3 feet of this space, and our platform body is 17 feet long, allowing the body to project 1 foot beyond the end of the frame. This allows 18 foot pipe to project 1 foot beyond the body with a total overhang of 2 feet beyond the end of the frame. This is permissible and within the bounds of good practice, as recommended by truck manufacturers. For flexibility and economic transportation, I would suggest that you purchase a heavy duty two-ton chassis, with which you can easily haul a load of four tons from your pipe lot to the job in question without abusing the equipment.

The smaller picture better shows the chain sling with a hook on each end. This was improvised by one of our foremen. The jack, shown in the foreground folded up underneath the crane platform, is one of two furnished with the crane. The jack on the side from which you are raising or lowering the load is unhooked and allowed to swing down to the ground to support the platform while you are loading or unloading.

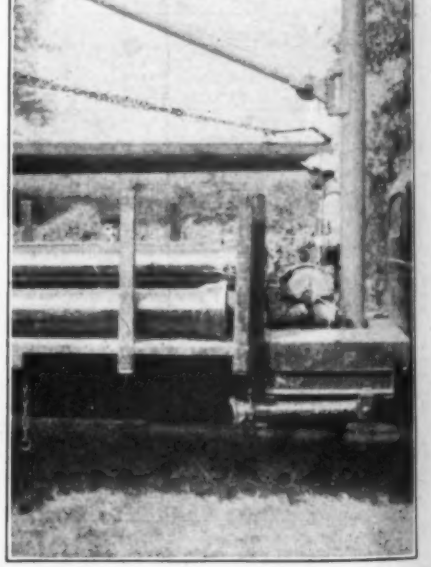
This crane can be obtained with various capacities and booms of several lengths. I would suggest that you purchase one of 3000 pounds capacity with a 10-foot boom. It may be of interest also to you to learn that the mast and boom is demountable and can be easily removed when not needed.

In the good old days, it required six men to unload a car of 8-inch pipe, but, with the outfit described above, three men can do the same job and do it quicker.

If interested in such a purchase and wish any more information, the writer will be glad to give it.

• • •

To Load 18-ft. Lengths of 8-in. Cast Iron Pipe With This Rig Is a Cinch



A Close-Up View Showing Power Crane, the Sling and One of the Support Jacks Beneath the Truck Bed

PRACTICAL ELECTRICITY IN THE PLANT

The A. B. C.'s of Electricity for the Water and Sewage Works Man

By MARSDEN C. SMITH

Engineer and Supt. Water and Electricity, Department Public Utilities, Richmond, Va.

Taken from a series of short articles by Mr. Smith, dealing with the A.B.C.'s of practical electricity for water works and sewage plant operators.

The author, a graduate electrical engineer, is a well known water works operator. He is, thereby, peculiarly well qualified to present these discussions, which should be of considerable benefit to operators and designers less thoroughly grounded in electrical matters.

If there are points in his contributions not clear to the reader, Mr. Smith offers to answer inquiries.

THE increasing use of electricity in water and sewage treatment plants produces problems of design, operation and maintenance with which the engineer in charge is generally but little familiar. Fortunately, while advanced electrical engineering is a very involved subject, a helpful and useful knowledge of its fundamental principles can be obtained quite readily by the trained personnel of such plant. To that limited end the presentation of this series of articles is confined.

PART I—ELECTRICAL UNITS

The Volt

One of the most important units of electricity is the Volt. It is the unit of electrical *pressure*. Just as we measure water force or pressure in units of pounds per square inch or feet of head, the unit of electromotive (electric moving) force is the volt. In equations, its symbol is E. Voltage is sometimes expressed in print as the emf—abbreviation for electric-motive force.

Standard voltages are 110, 220, 440, 2,200, 4,000, and 13,200. The individual for whom these articles are intended is rarely concerned with voltages in excess of 2,200. Furthermore, the 110 volt standard is now in the process of change, and seems to be quite generally replaced by a standard of 120 volts.

Extra-heavy fittings and greater precautions are necessary with greater water pressures; so too, must greater care be taken both of life and property when higher electrical pressures are used. However, pressures of as little as 110 volts, in common domestic use, may prove fatal and care should always be taken to avoid personal contact with even these relatively low pressure circuits.

Most electrical apparatus is designed to operate at one of the above mentioned standard voltages. The use of other than these standards is both unnecessary and uneconomical. Incandescent lamps are generally rated at from 110 to 125 volts in five-volt increments. They may be obtained designed for 220 volts, but such lamps are not recommended except where no 110-volt service is available. Even then safety and economy demand the use of 110-volt lamps if possible.

Some Practical Considerations

Lamps are very sensitive to voltage change; and the operator should see that the lamps are purchased for the circuits on which they are to be used. For example, if the average voltage at the station is known to be 118 volts, 120-volt lamps should be used. Here the use of 110-volt lamps would increase the lamp replacement cost by almost 300 per cent.

Motors are not nearly so sensitive to voltage change as are lamps and will operate successfully at applied voltages within 10 per cent above or below normal rated voltage. Greater voltage variation will generally cause excessive heating and unsuccessful operation.

Small motors (less than 5 horse-power) are usually single phase and operate at standard lamp voltages. Large motors, 5 to 50 H.P., are cheaper when designed for 220 or 440 volts. Larger than 50 H.P. should be designed for 2,200 volts. Of course, local conditions may change these recommendations. One large plant has motors from 3 to 300 H.P. The station designers used 2,200 to 440-volt transformers; motors between 50 to 300 H.P. were ordered for 440 volts. A second set of transformers reduced the 440 volts to 220 volts for the smaller motors (up to 50 H.P.). Certainly this is unfortunate, because the larger and more expensive motors would have been of less first cost if designed for 2,200 volts, and the 2 to 5 per cent transformer losses, which materially increases operating costs, would have been saved. The smaller motors could all have been 440-volt type, thus here again would have been saved the second transformer losses. Here we see an evident error that a better understanding of the problem of electricity in design would have avoided.

Other than electrical engineers often fear the use of 2,200 volts. It is true, that there is no need for this higher potential, unless the size and number of motors justifies its use. However, where the total of as much as two or three hundred horse-power is required for motors larger than 50 H.P., the higher potentials are certainly advisable.

The relative advantage of the use of 220 or 440 volts as the operating voltage for the smaller motors is not so definite. However, for larger plants 440 volts seems more desirable. Safety requires the same care with 220 volts as with 440 volts, and a much wider range of motor sizes can be more economically operated at this than at 220 volts.

The Ampere

The second important unit of electricity to be considered is the Ampere.

It is the unit of electrical *rate of flow*. We are familiar with the various measures of the rate of flow of liquids; gallons per minute, etc.; so we should think of the unit rate of flow of electricity as the ampere. In equations its symbol is generally (I). In print Amperes are sometimes abbreviated to "Amp." Larger pipes are required to carry larger rates of flow of water economically; so too, larger wires are needed to carry larger currents (amperes) economically. Small pipes may be uneconomical because friction causes too great loss of water pressure. In exactly the same way, wires may be too small for the amperage (current flow) and cause an uneconomical loss of electrical pressure (voltage drop).

There are no standard currents as in the case for the voltage rating of electrical apparatus. Each appliance, lamps, heating devices, etc., takes from the circuit a current dependent upon its design and lack of resistance to flow. Motors require, for example, a current that varies with the load. All electrical apparatus (except lamps) should have its normal current rating stamped upon its nameplate. Lamp current is determined by dividing its watt rating by its rated voltage.

However, there are certain appliances such as wire, fuses and switches that are rated in terms of the current they may safely carry; thus currents are to this extent standardized. The plant manager should realize that these current ratings are fixed by the National Electric Code, and he should not permit greater current to flow through accessories than the limits established by this code. Oftentimes circuits are fused far beyond the rated capacity of the wire, which is supposedly being protected by the fuse. Such practice is both uneconomical and dangerous.

Most appliances, including motors, are connected between the supply lines, that is, in parallel. In this way the circuit voltage is impressed upon each appliance, causing a current to flow through the appliance of a quantity dependent upon its rating and load. These increments of current are added, hence the supply wires carry greater and greater total current as we work back toward the source of power. For example: Five 1,000-watt

lamps rated 100 volts each require 10 amperes. Let us designate these as numbers one to five, from that nearest the supply to the most remote. Both wires between the supply and the first (No. 1) lamp carry 50 amperes; between 1 and 2, 40 amperes, and so on until between 4 and 5 the current has reduced to 10 amperes, or that required by No. 5—the last lamp. They all have (practically) the same voltages as the supply applied to their terminals.

Some Practical Considerations

When installing new apparatus there are two considerations of great importance: (1) Use wire of ample conductor size. (2) Employ insulation having a large factor of safety. For low potential circuits (less than 600 volts) 30 per cent pure rubber insulation will generally prove more economical than the standard code insulation. Particularly is this true in water and sewage treatment plants due to the prevalence of dampness in such locations. For 2,200-volt circuits rubber insulated cable is more easily installed than is varnished cambric cables. Rubber depreciates must more rapidly when subjected to heat and grease or oil than does varnished cambric, but it is less affected by moisture. For this reason, varnished cambric is never used without some form of outer coating, usually lead. Modern synthetic resins and other compounds are rapidly proving their value for use as the outer protective coating, materially lessening the installation difficulties. These coatings are deserving of consideration.

In general, where expert electrical maintenance is not available, the proper thickness of 30 per cent pure-rubber insulation, on conductors of adequate size for the current they will ever have to carry, will certainly well repay the increased investment cost. Where such expert maintenance is available, varnished cambric insulation may prove better for 2,200-volt circuits.

The Ohm

The unit of electrical resistance is the Ohm. In equations its symbol is (R).

If we close the spigot, even though there be water pressure at the valve, no water can flow because the resistance is too great. The same result is obtained when opening an electric switch; the pressure (voltage) still exists but the resistance (ohms) become so great that no current (amperes) can flow. This is an example of localized resistance.

Electrical resistance may be distributed, in fact *is* distributed along the conductor just as is the pipe resistance to water flow proportional to its size, length and condition. Fortunately, in electrical circuits the loss of voltage (pressure) is always directly proportional to the resistance and rate of current flow. Therefore, the loss of power (to be discussed in the next article) is proportional to the resistance and the square of the rate of flow or current.

An electrical device, such as a lamp, does not use or destroy current in the sense that an oil lamp consumes oil, but by its relatively high resistance limits the current that may flow as a result of the impressed electromotive force—voltage. Thus we have the simple but important equation known as Ohm's Law:

$$E = RI \quad \ldots\ldots (1)$$

There are no standards of resistance; however, the established resistance per unit length of electrical conductors and resistance alloys may be found in any electrical engineer's handbook.

Direct vs. Alternating Current

Formula (1) applies to circuits that contain resistance only, or in which the frequency is zero, as in the case of direct current. This term frequency must now be understood. If the polarity between two wires (A and B) of a circuit is not changed, the current flow will always be in one direction in the wires, thus constituting what is termed direct-current—(D.C.). If we alternate wires A and B from one side of the source to the other, once each ½ second, the direction of current flow in A and B will reverse once every ½ second, and will begin to flow in the original or *same* direction in a given conductor once every second. Electrically we would say that there was being produced "An electromotive force (current) having a frequency of one cycle per second." Fundamentally that is the difference between alternating and direct currents. Modern alternating currents closely follow the sine law in their time-potential value: and the standard frequency in this country is now sixty cycles per second.

When direct current is applied to a coil of copper or other wire (having resistance R) wound around iron, if the current and voltage be carefully measured, equation 1 will be found to apply. When an alternating voltage is applied this equation no longer can be used. This is because any magnetic circuit is an inductive circuit, and the effect of an inductance is to divide the alternating current into two components which are at right angles to one another. Hence to obtain the same current through the coil when an alternating voltage is applied, a greater voltage is required than when a direct voltage is used. So for alternating current circuits equation 1 becomes:

$$E = ZI \quad \ldots\ldots (2)$$

in which Z is the impedance of the circuit.

Many devices, such as heating appliances and lamps have little or no inductance; hence may be used on either direct or alternating current circuits of the rated voltage; but inductive devices, such as transformers and motors, cannot be used on direct current circuits unless especially designed for the purpose.

Transformers

The engineer for whom these articles are intended rarely is concerned with the use of transformers; however, a brief discussion of them is advisable. The standard transformer consists of two stationary coils of wire insulated from one another and wound around a common iron core. A special class, the auto-transformer, commonly used for motor starters, has only one winding with connections to some desired turn between the two end turns.

Of the winding in the auto-transformers, the turns connected to the power supply is the primary; the secondary winding is connected to the load. The voltage change between the primary and secondary is in direct ratio to the number of turns used in the two windings; conversely, the current is in the inverse ratio to the number of turns. Hence a transformer may be used to increase voltage as readily as to reduce it—the so-called "step-down." Many deaths have resulted from opening the high voltage switch, assuming the transformer "dead," when in fact the 110-volt side was still energized thus producing normal high voltage in the primary.

Instrument transformers are especially designed to accurately reduce the potential or current, as the case may be, for metering and other purposes. Care should be taken to always connect the secondary terminals of current transformers together with wire (short-circuit them) if the secondary circuit must be disconnected for any purpose while the primary continues to carry current.

It is well to know that transformers, if kept cool enough, can safely carry much greater than rated loads. Cold winter weather and artificial ventilation around the tanks is effective, but hot locations and days are dangerous. Tank temperatures should never exceed 90 degrees C. Contamination of the oil by dirt or even traces of moisture must be avoided. In larger units the oil should be examined monthly by a competent inspector.

The Watt

Another very important unit of electricity is the Watt, which is the unit of electrical power. The more commonly used unit is the Kilowatt, which is one thousand watts. The symbol for the Watt is (W); for the Kilowatt (KW). The mechanical unit of power is horse-power; one horse-power (H.P.) is the equivalent of 746 watts or 0.746 kilowatts. Due to the fact that the efficiency of small motors is approximately 75 per cent, the input in kilowatts is, by coincidence, closely the same as the mechanical output in horse-power.

With direct current, electrical power is the product of the current (I) and the voltage (E). Thus we have:

$$P = EI \quad \ldots\ldots (3)$$

However, substituting for (E) from equation (1), wherein $E = RI$, we have;

$$P = RI^2 \quad \ldots\ldots (4)$$

Or similarly, substituting for (I) where $I = \frac{E}{R}$ in the same equation:

$$P = \frac{E^2}{R} \quad \ldots\ldots (5)$$

Now, it becomes evident that electrical power varies directly with both current and voltage, if resistance is not considered, but as the square of either (E or I) if the resistance is considered.

PART 2

POWER FACTOR; ITS SIGNIFICANCE

With alternating currents equation (3) becomes the more familiar form, and—

$$P = EI \cos \theta \quad \ldots\ldots (6)$$

In this equation the Cos θ is designated as the power-factor. If an alternating current circuit contains resistance only (no capacity or inductance) the angle θ becomes zero; hence, its

cosine, which is the power-factor becomes unity. Electrical installations in water and sewage treatment plants rarely contain sufficient capacity (condenser action) to be of any practical effect, hence we may omit further reference to "capacity" in these articles. Inductance, however, is of great importance, and in practical installations may reduce the power factor as much as 30 per cent.

The actual mathematical value of the power-factor of practical circuits is difficult to compute; however, it is well for the engineer to have some idea as to the values that may be expected. Incandescent lamps and heating devices, since they contain but little inductance, are virtually non-inductive; hence, their power-factor closely approaches unity. Motors and transformers vary through very wide limits. Of course, a transformer being highly inductive when delivering no load, its power-factor is quite near zero; but, at rated load the power-factor becomes quite nearly that of the circuit being supplied by the transformer. Small motors, up to 5 h.p., require power at not more than 60 per cent power-factor; particularly so when operating at light loads. Large induction motors, at full load, now may operate at as high as 94 per cent; and, synchronous motors, more fully discussed in coming articles, may be operated almost as desired.

The objection to low power-factors is that larger currents are required for the same power, thus increasing power losses in the whole electrical system. Furthermore, low power-factors cause much wider voltage variations than do greater loads with higher power-factors. For this reason many power companies offer reduced rates to those consumers whose apparatus constitutes a load having a favorable power-factor. This fact may be of value to many larger operators. It is true, however, that plant operators can exercise but limited control over the power-factor of their stations except through the selection and operation of the motors. This phase of the subject will be later discussed when motors and their characteristics are considered.

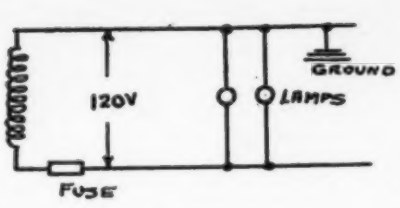


FIG 1

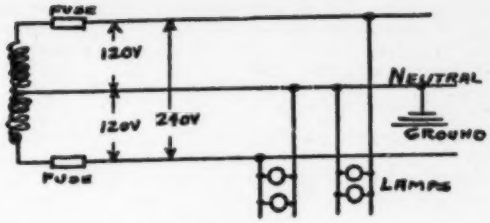


FIG 2

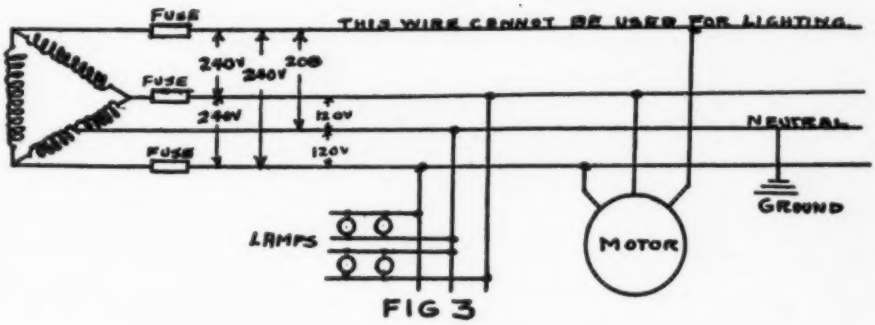


FIG 3

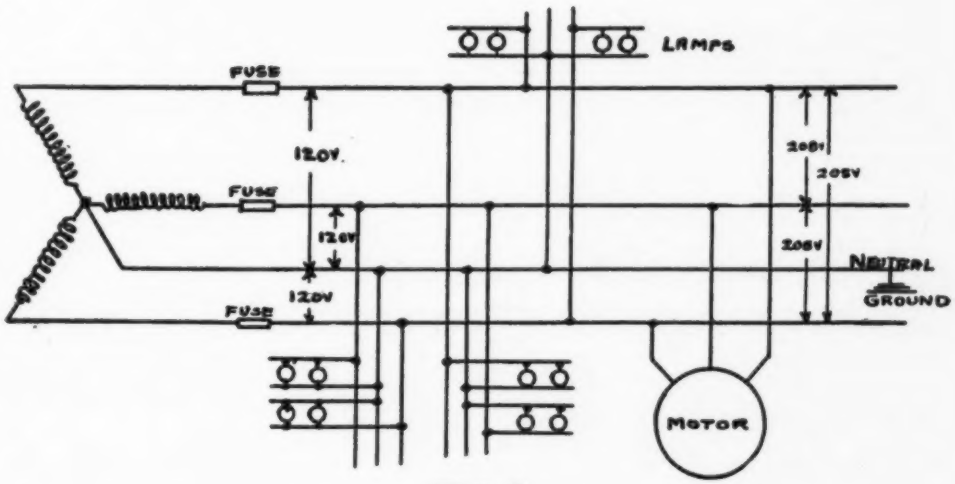


FIG 4

Circuits: Figs. 1, 2, 3 and 4

The Kilowatt-Hour

The kilowatt-hour (KwHr) is the unit by which electric power is generally sold. As its name implies, it is the average power consumed, in kilowatts, multiplied by the number of hours involved. For example: if an electric iron is operated for two hours at average rating of 600 watts, there is used $600 \times 2 = 1200$ watt-hours, or 1.2 KwHrs.

The volt-ampere (VA) is the product of the volts and amperes of a circuit or an appliance, without reference to power. Thus, the transformer is always rated in kilo-volt-amperes (KVA) because its parts can be designed for the voltage and current value desired, but the power-factor of its load may vary through wide limits. Thus we see that:

$$KW = KVA \times \text{Cos } \theta \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Hence, if we are to know the safe load for a transformer rated at 100 KVA, we must first determine the power-factor of the load to be connected. If we may assume the load to be one-half lamps and one-half small motors; we may approximate the average power-factor to be 82 per cent. Hence, by equation (7) we find $Kw = 100 \times 0.82$ (82 Kw) to be the safe load for this case.

The Cos θ, which we now recognize to be the power-factor, is actually the cosine of the angle of time-phase displacement between the current and the voltage of an alternating current circuit containing "capacity" or inductance.

Circuits

The term, "phase," is also applied to designate the circuits of an alternating current system. In the "Single-Phase" system the *voltages* are in the same time-phase in all parts of the system. In the "Two-Phase" system, the two voltages are 90 degrees apart. In the "Three-Phase" system they are 120 degrees apart.

In another sense, there are in effect one or two or three circuits in the single, the two or the three-phase systems. Of course, the power-factor may be different in each phase; hence the currents in the phases may not be of exactly the same angular difference as the voltages producing these currents.

The simplest circuit is that comprising the single-phase (two-wire) system, as in Fig. 1. This is used for the final branch circuit of larger systems, and in case of small loads, including most residences, it is always used.

The single-phase, three-wire system is next in capacity and in frequency of use. Single-phase, two-wire branches are connected thereto as shown in Fig. 2. The evident advantage of three wires over the two-wire system is that when loads are

balanced, the neutral carries no return current, hence the lamps and appliances operate at 120 volts, whereas the circuit operates at 240 volts. In this way twice as much power can be carried over the same wires, by merely adding one additional wire.

Grounding Practice

The neutral must be grounded. It should be the same size as the phase wires; and, it must *not* be fused or connected to any switch, and the wire used for the neutral must have white covering for identification, and the neutral must be connected to the white screw in all receptacles. In the single-phase, two-wire system one of the wires must be grounded and the same rules as given for the neutral conductor wire must be observed.

(Grounding practice as it affects water works piping will be given some discussion at a later point in this article.)

Three-Phase Standard for Heavy Duty

The three-phase (three-wire) system is standard for motor loads. If lighting is required, the neutral of one transformer (made larger to carry the additional load) is brought out as in Fig. 3. Most power companies limit the single-phase load that may thus be supplied to 50 KVA. In addition, this method of supplying the lighting loads makes service interruptions more frequent because of the necessity for grounding one of the transformer windings. Perhaps most serious of all is the objectionable flicker in the lights obtained when starting motors, particularly elevators connected to the system. Of course, economy often rules and hence this system is frequently used; but unless the motors are relatively small, and are started very infrequently; it is undoubtedly better to separate the lighting and very small motors from the power system.

The formula for power in the different systems, with balanced load, is given in the following table:

System	*Power*		*Max. Volts to Ground*
Single-Phase (Two-Wire)	$P = EI\cos\theta$	Here E=120	120
Single-Phase (Three-Wire)	$P = EI\cos\theta$	Here E=240	120
Two-Phase (Four-Wire)	$P = 2EI\cos\theta$	Here E=120	120
Three-Phase (Delta)	$P = \sqrt{3}EI\cos\theta$	Here E=240	207.8*
Three-Phase (Y)	$P = \sqrt{3}EI\cos\theta$	Here E=207.8	120

*Volts to ground on lighting circuits is 120.

The two-phase (four-wire) system is so little used that no discussion is necessary.

PART 3—CIRCUIT PROTECTION

Fuses and all electrical circuit-breakers are similar in function to the safety valve on a boiler; and hence they should be seriously considered. They are all intended to open the circuit, thus stopping the flow of current, should the current exceed a predetermined or dangerous rate through these safety devices.

While the problem of circuit protection becomes at times quite involved, still there is much that can here be discussed to advantage. In the first place, the Natinal Electric Code is now almost universally accepted as the authority for the safe utilization of electricity in all except central station systems. Consequently, the engineer should obtain a copy of this useful and important publication.

Fuses and Circuit Breakers

Fuses are the cheapest and simplest of all protective devices. They consist of a piece of relatively high resistance alloy wire or tape, designed to melt, and thereby part, at the current at which the fuse is rated. The wire is enclosed in a suitable flame-proof case to prevent ignition of surrounding materials at the time the fuse flashes and melts. The use of fuses is now confined almost entirely to circuits the importance of which does not justify the more expensive and accurate devices. The type now approved, known as the "refillable type," permits the renewal of the fuse link, using the expensive part (the cartridge) over and over again.

For those applications in which the replacement of fuses is frequently necessary, thermal relays or air circuit breakers are to be recommended. Motor circuits fall in this classification. Thermal relays and circuit breakers can permit a greater than rated current pass for a short time, as during the starting period of a motor, and therefore are of especial advantage for this service. The current capacity as well as the voltage ratings of this class of protective devices are limited, and when greater limits are needed the oil circuit breaker must be used.

The oil used in circuit breakers must be especially selected for this service; and no other oil should ever be used. This precaution is essential for the reason that the oil must have high insulation value, high flash point, low carbon content, and wide temperature viscosity constant—all in order to quickly quench the arc that is formed with each opening of the contacts.

Relays

The overload operation of an oil circuit breaker is usually actuated by an auxiliary device known as a relay. Relays may be of several types: the instantaneous, the inverse time limit, and others. The modern relays are truly marvelous devices; however, the types needed by the water works plants are, in the main:

(1) *The Instantaneous Type*—dash-potted relays with direct mechanical trip. Here a coil which carries all or a definite part of the load current raises a solenoid when the current flow exceeds a predetermined value. The rising solenoid mechanically releases a trigger, which in turn permits the oil circuit breaker to open. An oil-filled dash-pot retards the solenoid movement. The dash-pot opening is adjustable, hence the time for opening with a given over-current can be selected as desired. The oil in the dash-pot should be inspected at intervals and replaced if dirt or sludge has accumulated. While rather crude, this device is sufficiently accurate for the protection of most small motor circuits.

(2) *The Air Bellows Type*—This type is not much used now. An air bellows, with an adjustable escape valve, is substituted for the oil dash-pot described above.

(3) *The Induction Type*—This relay is more expensive than those above mentioned, but its use is justified in the protection of all important cicuits.

With the induction relay, when the current exceeds the desired value, the torque on an aluminum disc, mounted on the same shaft with the relay contacts, causing the shaft to rotate. Such rotation causes the opening (some cases the closing) of the relay contacts, which in turn electrically energize the main tripping coil on the circuit breaker. The advantage of this type is that the time of opening the main circuit breaker can be determined to a fraction of a second; also, that the limits of control are so wide that these relays, with suitable current transformers, become almost universally applicable and highly accurate protective devices.

To repeat, too much care cannot be given the subject of circuit protection. Over-fusing (use of fuses with too great capacity) of circuits is dangerous and uneconomical. Noting a too frequent operation of the overload, protection of any appliance warrants prompt investigation. The source of the trouble should be remedied by correction, rather than following the easiest path of using too large circuit protection to overcome an annoying operating circumstance.

Grounding—Its Essentiality

It is no exaggeration to say that without adequate grounding, satisfactory electrical service would be virtually unknown. In addition, safety would be a word more than a reality. Even so, many groundings are so deficient in quality as to become actually a hazard instead of a safety effect. Many persons have been swindled into paying for a false sense of security when installing lightning rods having many ornamental glass balls but no grounds. Thereby the victim is actually inviting the lightning to strike the house but offering no protection by way of a cable or rod to conduct the electric discharge into the earth and there dissipate it.

Grounds should be carefully made. Use not less than No. 2 B&S gauge copper wire. Several grounds are preferable to a single ground in order to lessen the chances of broken connections. Use the water pipe system; the larger the pipe, the better. Do not use the gas, gasoline or oil pipe lines. Be sure the connection between the wire and pipe is electrically and mechanically as perfect as possible. If no pipe system is available, drive at least three 1¼-inch pipe, or equivalent copper rods, *well below the moisture line* in the earth. A good test is that the driven ground connection, when shorted, should blow a 30-ampere fuse at 120 volts.

Much discussion has recently been raised in the water works field as to the effects of attaching the electric circuit "neutral" wires to the water pipes. There is no question that the damage done to water systems by stray direct currents, as from street railways, has been indeed enormous. Here we have electrolysis at its worst, and the destruction of the metallic pipes at spots where the current leaves the pipes is rapid. This condition is inexcusable and should be prohibited everywhere.

However, in the alternating current system the damage is not so evident, and many doubt its *real* existence—or at least its seriousness. Also it is quite possible that were all connections between electrical and water systems removed, electrical service as we know it today would be a thing of the past. And even should such action force the electric companies to seek other means of obtaining the necessary protection now provided by these ground-

ng attachments, the water systems would be subject to the same distress now *debatedly* suffered. It would seem certain that more severe difficulties would be caused by the same currents finding their way to the water system in a then uncontrolled routing and dissipation which present practices have been designed to effect.

The necessity for grounding the electric circuits is to prevent dangerous high-potential voltages (through mistakes or accidental contact) from increasing the normally low-potential circuits to a dangerous loading. The wiring for lighting systems of buildings is designed for a maximum of 150 volts to ground. Let us assume that a street series circuit operating at 5,000 volts should fall across the service wires from the pole to your home. With no ground on the "neutral" of your secondary wiring, its potential would be raised from its normal low value to a maximum of 5,000 volts. Certainly something must happen; either a fire is started, or perhaps a member of your family may be killed. The effect of such danger has been observed when service thawing current reaches the house wiring. In these instances the "ground" has worked in reverse, but proves its safety value and the necessity of "breaking" the service line before electrical thawing is started. Now consider these same conditions to exist, except that now your "neutral" is properly grounded. When the high-potential circuit is now temporarily crossed with service, the high-potential currents are safely carried to ground, and no one in the home would realize the possible disaster that the ground connections have avoided.

When, What and Why Ground?

There is no doubt that a full study and discussion of the entire subject of grounding by the new functioning joint committee will prove well worth while. It is certainly to be hoped that there will result a greater care in the preparation and arrangement of ground connections between the electric and water systems, and that the volume of curent flow be intelligently regulated. We, the water utility interests, should not embarrass this effort by hasty demands to prohibit all grounding of water systems. As a matter of fact, we could not do so, even if thoughtless enough to demand such.

[Water works men have themselves found difficulty in effectively grounding pumping station motor circuits by any other method than an efficient connection to their own pressure mains leaving the station.—Ed.]

No wires used in lighting systems should have more than 150 volts to ground. The wires of power circuits, such as 220 or 440 volts, *should not be grounded.* All appliances, frames of motors, conduit, etc., in addition to the "neutrals" of lighting systems, should be carefully and effectively grounded. Inspect grounds frequently. The snuffing out of a life may be the penalty if you do not. Satisfactory operation is another, if secondary, reason for so doing.

PART 4—MOTORS

Alternating current motors are of two general types: the synchronous and induction. The main difference between these two types is that, while the synchronous motor can run only at a definite constant speed (synchronous speed), the induction motor must operate at a speed dependent upon the load applied, but never at synchronous speed. There are other important differences that, to better advantage, will be mentioned later.

Synchronous Type

At a given frequency the speed of a synchronous motor may be determined by the equation;

$$N = \frac{120f}{P} \quad \ldots\ldots\ldots (8)$$

in which N = revolutions of rotor per minute (RPM); f = frequency in cycles per second; P = number of poles.

Since the standard frequency is 60 cycles per second, equation 8 is generally expressed in the form:

$$N = \frac{7200}{P} \quad \ldots\ldots\ldots (9)$$

From this it is evident that the maximum speed for a 60 cycle motor is 7200/2 or 3600 RPM, and the speed, N, from equations 8 or 9 is known as the synchronous speed of the motor. This, for 60 cycle motors, is the constant 7200 divided by the number of poles; and, since the number of poles must be an even number, synchronous speeds become 3600, 1800, 1200, 900....RPM. One of the greatest limitations of the synchronous motor is that it cannot be built to operate at other than synchronous speeds, when oftentimes an intermediate speed is needed.

On the other hand, the fact that it runs at an exact speed is quite frequently its greatest asset. Electric clocks and timing devices depend upon this characteristic for their value and dependability as to accuracy. Pump drives, and mechanical devices of all types that require an exact and fixed speed, necessitate the use of the synchronous motor for this reason.

Another marked difference between the synchronous and induction motor is that the former requires salient magnetic poles, excited (magnetized) from a source of direct current; whereas, the induction motor has no such poles and requires no separate excitation. In fact, the standard squirrel-cage motor is well named, because its rotor is essentially nothing more than a circle of bars parallel to the shaft which are held in place and short-circuited by two metallic rings. Picture the revolving cage for the squirrel's exercise and you have it—thus, the name.

Unfavorable Characteristics

The necessity for this auxiliary direct current is indeed unfortunate, because direct current generators are difficult to maintain. Hence, greater skill and maintenance are required for synchronous than for induction motor operation. Then, too, the starting characteristics of the synchronous motor are rarely satisfactory. The starting torque (that is, the twist or pull) cannot approach that of the induction motor; frequently necessitating expensive and complicated methods of holding the load off the motor until it has reached full speed. Fortunately, centrifugal pumps may frequently be started under no-load without inconvenience, which renders this deficiency of the synchronous motor of no real importance.

Favorable Characteristics

On the favorable side of the ledger, the synchronous motor does possess the ability to operate with a "leading" power factor, contrasted to the rather decidedly "lagging" power factor of the standard induction motor. As has been stated previously, many power companies offer a lower rate to consumers whose requirements make permissible a desirable power factor. Where this is the case, the ability of the synchronous motor to operate at the "leading" power factor may have influence in the selection of the type of motor to be adopted.

From the above, it can be seen why, for water works and sewage treatment plants, the use of synchronous motors is frequently advised against. They are only to be considered when exact speed is essential or power costs may be lowered appreciably by the favorable power factor. Even then, the engineer will do well to be certain that savings in power bills will offset the increased operating difficulties that are certain to be realized in the use of synchronous motors.

Induction Type

The induction motor differs from the synchronous type in that it requires no separate excitation, and its ability to operate at a variable speed, as contrasted to the constant speed synchronous motor.

At no load an induction motor will run almost up to its synchronous speed. It should be understood that while the induction motor has no salient poles, the stator is wound to produce two, four or any even number of poles, just as is the stator of a synchronous motor; hence it has a synchronous speed of 3600, 1800, 900 RPM, just as does the synchronous type.

As the load on an induction motor is increased, the speed gradually lessens until at full rated load the speed is reduced from two to four per cent of its synchronous speed. Thus a given motor may have a synchronous speed of 1200 RPM, a no load speed of 1199 RPM and a full load speed of only 1170 RPM. If the load is further increased, the "slip" (as the loss of speed is called) will increase until a definite value is reached, at which point the motor will come to a stop. This load is known as the "pull-out" load.

Favorable Characteristics

Standard induction motors have very favorable starting characteristics, requiring relatively a small starting current and producing 200 or more per cent of full load torque. They are the most rugged and reliable of all motors. But while they will successfully operate under most adverse conditions, reasonable care should be taken to keep the air ducts and windings free from lint and dirt. The oil in the bearings must be flushed and changed at least once each year.

Smaller and specially designed induction motors require no starting device, and may be started by applying normal full voltage. Larger motors require reduced voltage for starting, which is

usually obtained from auto-transformers, called starting compensators. Two coils, each on an iron core, are connected open-delta across the three-phase lines; a 40, 50 or 60 per cent tap is taken to the motors for starting. After the motor has started and reached a constant speed, the compensator is disconnected and full voltage goes to the motor.

Variable Speed Motors

The wound-rotor induction motor, for operating at variable speeds, is not so rugged as is the standard squirrel-cage type. It is more expensive and also usually less efficient. A misunderstanding of the speed characteristics of these motors has caused no end of trouble. We may gain a clear conception of the speed variation of the wound rotor, induction type motor if we think in terms of "slip." As stated above, the standard squirrel-cage motor "slip" varies from virtually nothing at no load to about 3 per cent at full load. With the wound rotor, external resistance may be added to the rotor circuit, the effort of which is to *increase* the slip. Hence, this motor will run at essentially *constant* speed at no load, regardless of the amount of external resistance introduced in the rotor circuit. But, as the load is applied, and the greater is the external resistance, the more rapidly will the speed drop off.

Practically, this means that if we desire to drive a centrifugal pump at a variable speed, in order to vary the head and quantity delivered, we must first learn from the pump manufacturer both the speed and the horse-power required by the pump for each value of head-quantity desired. This data is then furnished the manufacturer of the motor who will design the external rotor resistances so that the various controller positions will connect the correct resistance to cause the speed to be that needed for the pump to operate under the desired condition.

Since power is a product of speed and torque, it should be remembered that less horse-power output can be obtained from a motor operating at a reduced speed than at its normal full speed. The reduction in motor output is approximately proportional to the reduction in speed. This fact should be considered at the time of purchase in order to be certain that the motor will not be excessively heated when operating at any of the reduced speeds. The same resistors that serve for speed control are also used for starting, hence no compensator is required as is the case for some of the standard squirrel-cage types.

Motor Ratings

The rating of most electrical apparatus such as motors, transformers, etc., is based upon the temperature rise that will occur when the device is operated continuously under normal full load and normal voltage conditions. Many manufacturers recommend a limit of fifty-five degrees centigrade rise, while other base their estimates upon a rise of only forty degrees. After all, this simply means that with a given motor rated at 100 HP, at 40 degree rise would be rated at 125 HP at 55 degree rise. All things considered, it seems to be the consensus of opinion, and dictate of wisdom, that all important motors in water works and sewage treatment plants should be purchased for a guaranteed rise, not to exceed forty degrees centigrade.

Hazleton Type "M"

CHECK VALVE

with Built-in Mercoid Motor Shut-off Switch for Automatic Pump Protection

PROTECTS PUMP FROM DAMAGE DUE TO LOSS OF WATER

PREVENTS OPERATION OF PUMP UNTIL PROPERLY PRIMED

The purpose of the flow switch is to insure pump against damage in the event that the pump loses its water during operation. The mercoid switch is actuated by the valve flap. Normally the switch is open when the flap is down. When the pump delivers water, the flow through the valve raises the flap and closes the switch. The mercoid switch is connected into the no-voltage coil of the motor starter.

When using a hand starter, the pump can be started up by hand, whether delivering water or not, but when the hand is removed from the starting lever, the pump will immediately stop unless the pump is delivering water and the mercoid switch of the check valve closed. With an automatic starter the "start" push button must be held in until the pump delivers water and closes the check valve switch.

Let us quote on your requirements

BARRETT, HAENTJENS & CO. - - Hazleton, Penna.

A TIME SAVING CALCULATOR

By V. W. PALEN*
Pittsburgh, Pa.

PLANT engineers and electricians will find a KVA-KW-HP Calculator a very useful gadget to have on hand—it saves much time in making routine calculations involving electrical capacities. It solves single and three-phase problems expressed by the following formulae:

Single Phase

$$\text{Kva} = \frac{\text{Volts} \times \text{Amps}}{1000}$$

$$\text{Kw} = \frac{\text{Volts} \times \text{Amps} \times \text{P.F.}}{1000}$$

$$\text{Hp} = \frac{\text{Volts} \times \text{Amps} \times \text{P.F.}}{746}$$

Three Phase

$$\text{Kva} = \frac{\sqrt{3}\ \text{Volts} \times \text{Amps}}{1000}$$

$$\text{Kw} = \frac{\sqrt{3}\ \text{Volts} \times \text{Amps} \times \text{P.F.}}{1000}$$

$$\text{Hp} = \frac{\sqrt{3}\ \text{Volts} \times \text{Amps} \times \text{P.F.}}{746}$$

The range of the calculator 5 to 200 (Kva, Kw or Hp, as the case may be) can be extended easily to cover a range of 50 to 2,000 merely by multiplying all values by 10. It can be used to find Kva, Kw or Hp from known values of amps and volts; similarly it will determine amps for given values of voltage, Kva, Kw and Hp. Thus, knowing the size motor to be installed, an electrician can quickly determine amps—from this he knows what size wire to use for the circuit. Conversely, having read amps at transformer terminals—the calculator tells what load, in Kva, the transformer is carrying.

To assemble, cut out both discs (also small windows) and mount on cardboard with rubber cement. Punch the center holes carefully—then insert a small brass bolt in the holes. Washers, if used will save wear and tear on the paper. The bolt should be tightened to give the proper pressure on the discs—they must hold their setting, yet turn easily. A drop of solder applied to the nut will make the assembly permanent.

*Editorial Service—Westinghouse Elec. & Mfg. Co.

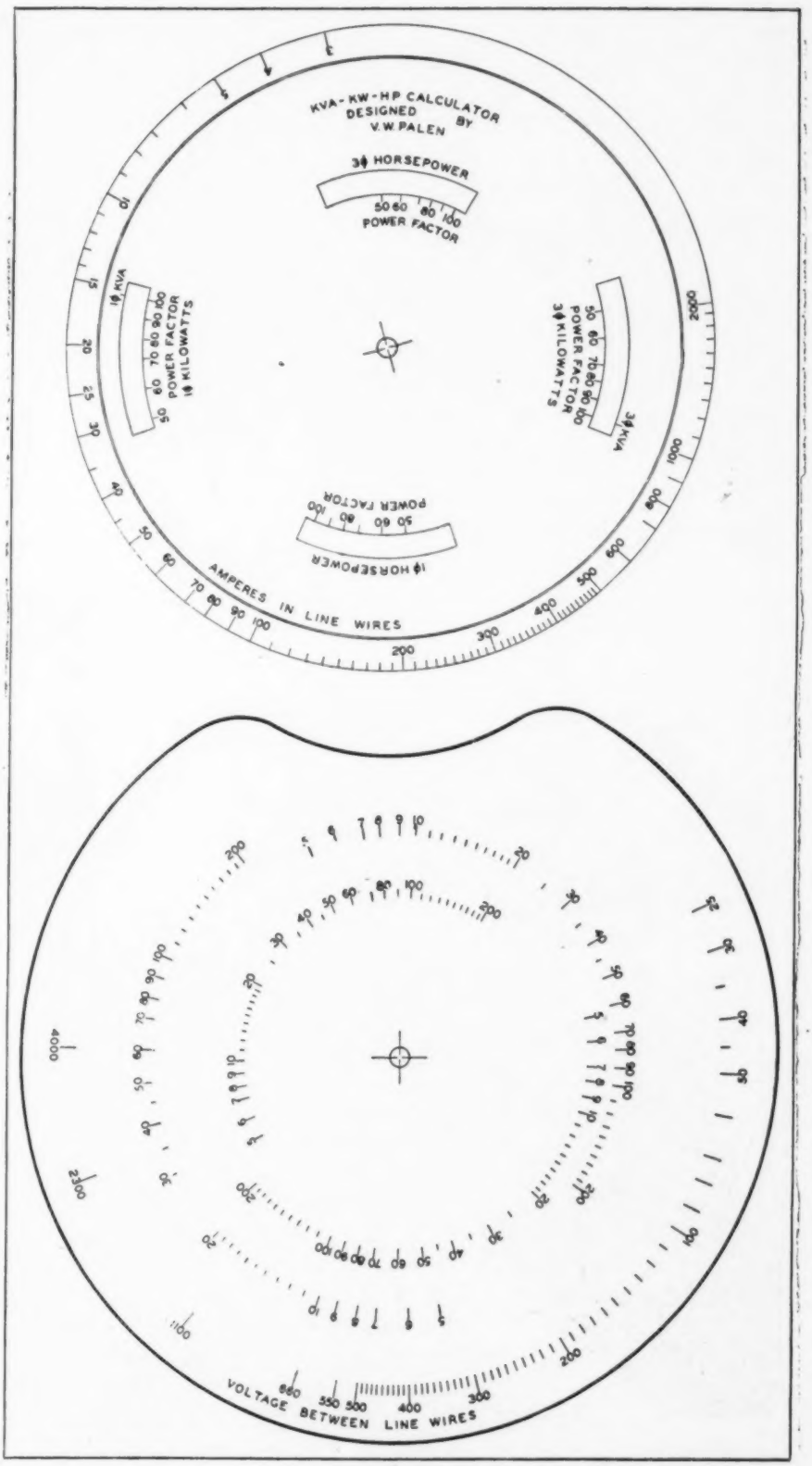
HORSE-POWER AND ELECTRICAL DATA

(a) 1 H.P. = 0.746 KW. = 746 watts.

(b) Brake H.P. $= \dfrac{\text{KW. input}}{0.746} \times$ motor efficiency.

(c) Water H.P. $= \dfrac{\text{g.p.m.} \times \text{head in ft.}}{3960}$.

(d) H.P. to lift water $= \dfrac{\text{g.p.m.} \times \text{head in ft.}}{3960 \times \text{pump efficiency.}}$



KVA-KW-HP Calculator

[NOTE: *If a photograph is made of this cut on heavy glossy paper it can be worked with much more easily in making the calculator. And extra prints may be made from the negative as required.*—EDITOR.]

R. W. SPARLING

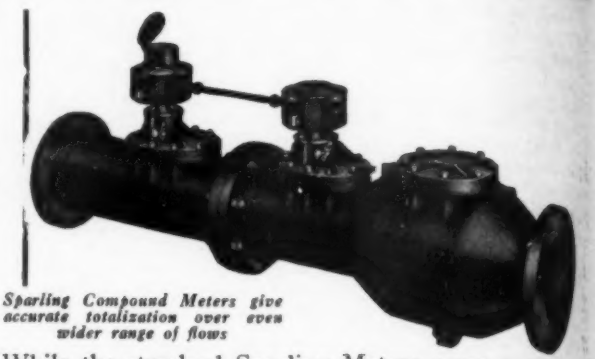
MANUFACTURER OF

MAIN-LINE WATER MEASURING EQUIPMENT

Box 3277 Terminal Annex, LOS ANGELES 54 — 3104 S. Michigan Avenue, CHICAGO 16
622 Broadway, CINCINNATI 2 — 101 Park Avenue, NEW YORK 17 — 6 Beacon Street, BOSTON 8

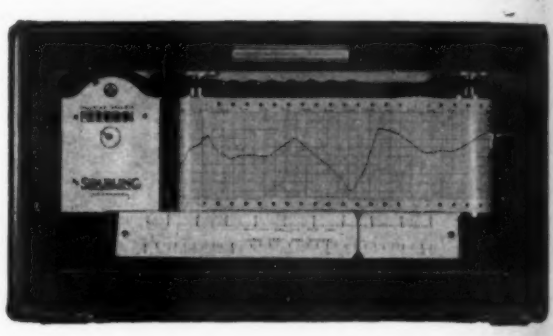
ACCURATE . . . DURABLE

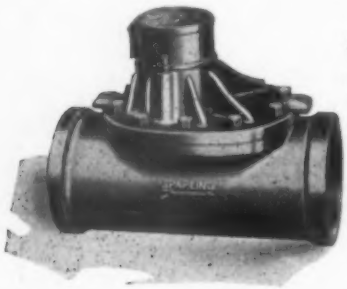
Propeller-type meters for main-lines are the choice of waterworks operators, industrial engineers and U. S. engineers. The one shown above is a complete totalizing meter in a flanged tube ready to be installed just as though it were a length of the pipe itself.



Sparling Compound Meters give accurate totalization over even wider range of flows

While the standard Sparling Meters cover a range of flows sufficiently wide for most water systems, Compound meters are available (or a compounding section can be added to Sparling meters already in operation) to give accurate registration for flows up to 1 to 120.

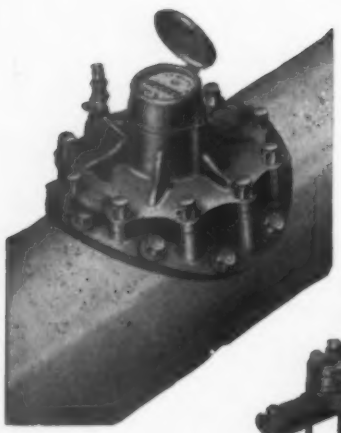


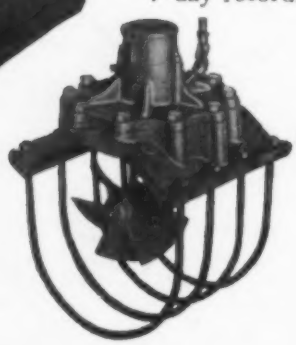


Screw-tube meters are available in sizes for 2-, 3-, 4-, 5- and 6-inch lines. The 2-inch meter is listed at $75. Flanged tube meters from 2-inch to 36-inch.

METERS—CONTROLS INDICATORS—RECORDERS

Flow-rate indicators and recorders can be added if, as and when required, operating either at or at any distance from the meter. Above is Totalizer-Indicator-Recorder with equal calibration over the range of flows and straight-line charts for periods up to 60 days. At right, the mercury-governor recorders use circular charts for 24-hour or 7-day records.





Two types of Sparling meters for mounting on the line itself—a simple job for the average mechanic.

At right is a Bell & Spigot tube meter — for lines from 4-inch to 36-inch. All Sparling Meters are guaranteed for accuracy within 2 per cent within the rated range.

Write for Catalog Bulletin 308

SELECTION OF MAIN LINE METERS

With a Set of Charts Designed to Simplify the Problem

By J. C. THORESEN
Engineer
Builders-Providence, Inc., Providence, R. I.

IN the selection of suitable meters for main gravity and pump discharge pipe lines, price is too frequently the sole determining factor, whereas a closer examination of the proposals may demonstrate that such a decision would be definitely improper from an economic standpoint. This does not assert that the lowest priced equipment is never warranted, but simply that experience has repeatedly emphasized the importance of making an evaluation of design and specifications. These include the reputation of the meter; its anticipated life; materials, workmanship and finish; probable cost of maintenance; character of information furnished, such as size of dials and charts, uniformity of graduations, whether direct reading in units of flow or indirect in nominal values or differentials; and, most important, the friction loss induced. It is not the purpose of this paper to comprehend all of these, but to devote the discussion to the last mentioned, the friction loss, resulting in loss of pressure, or power, or both, occasioned by the insertion of the flow measuring element in the pipe line.

For gravity lines under low heads, the friction loss of the proposed meter should be carefully studied to determine whether objectionable in its effect on the hydraulic gradient. In a pump discharge line, friction loss alone may not be of significance, but when considered together with pipe line size and hours of operation, the combination of these three factors may be of great monetary importance in a 12 months' period.

In general, main line meters operate on the inferential principle: that is, the flow rate is "inferred" from the difference in pressure induced by a "restriction" placed in the pipe line and transmitted to the recording instrument, through which no flow occurs. It is readily appreciated by all water works men that elbows, tees, partly closed valves or other fittings add to pipe line friction loss and must be reckoned with in the design of the system. So it is with meters. Whether water is first lifted to a reservoir or pumped directly through the pipe line, the additional load is reflected back upon the pumps, requiring provision for more horsepower than would otherwise be required, and power always costs money.

Forms of Differential Producers

There are only a few forms of "differential producers" for insertion in pipe lines. Of these, the Venturi Tube and Orifice Plate are by far the most widely employed. They are entirely unlike in their construction.

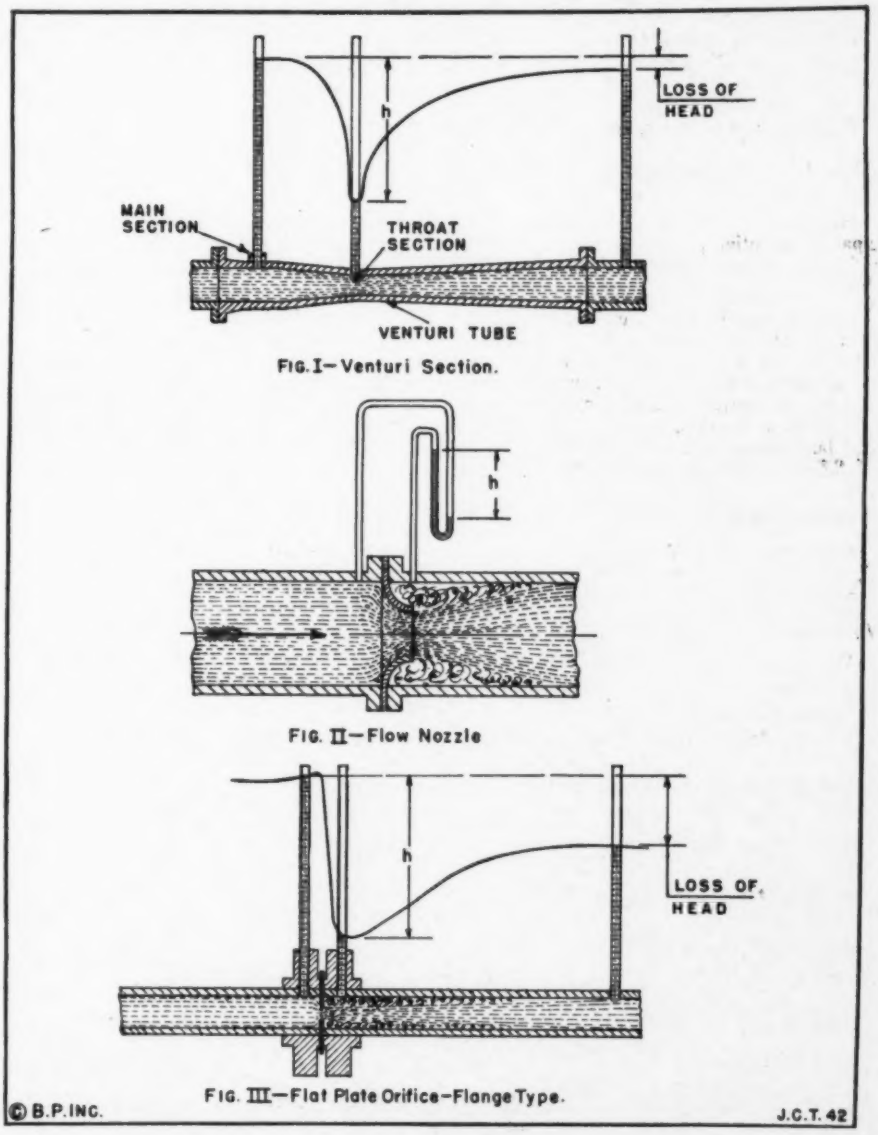
The Orifice (Fig. III) is essentially a flat plate between flanges of the main pipe. As the flowing water approaches the Plate, the stream lines undergo an abrupt (nearly 90 degree) change in direction; then, after passing through the Orifice opening, start to expand again until finally the pipe line is completely filled. As would be expected, there is considerable turbulence in the surrounding annular space on both sides of the Orifice occasioning a relatively high over all pressure head loss.

The Venturi Tube

The Herschel Standard Venturi Tube (Fig. I) is of "streamlined" proportions. It forms a section of the pipe line. As the flow progresses from the inlet section there is a rapid acceleration of velocity with decreasing pressure until the "throat" is reached, where the speed of flow may be ten or more times as great as at the inlet. After passing the throat, the velocity is decelerated through a gently expanding outlet cone, with consequent gradual regain in pressure. The velocity distribution is equal across the throat and the rate of flow is based upon the throat area. Throughout this interchange of velocity and pressure, there is wall guidance of the flowing stream and turbulence is avoided. For this reason the standard Venturi Tube has definite advantage over the Orifice in the important matter of pressure loss.

Orifice Plates and Nozzles

Fig. II illustrates one form of the "Nozzle", of which there are various designs. The type shown is slightly better than the Orifice in pressure loss characteristics, but not enough to warrant separate consideration. The graph (Fig. IV) shows the comparison of friction loss for the three differential producers mentioned. The steep slope of the two upper curves for the Orifice and Nozzle are in sharp contrast to the Venturi curve: in the Venturi the friction loss changes but a few per cent for a wide range of the throat diameter to inlet diameter ratio (d_2/d_1) in contrast with the other two devices. It will be observed that



Figs. I, II and III—Three Forms of Differential Producers for Main Line Metering.

the friction loss is in per cent of the Orifice or Venturi differential head (i.e.—head at inlet minus head at throat) which may reach a maximum of 10 to 20 feet of water, if not more, for accurate metering.

A reduction in the unrecoverable loss of head through an Orifice or Nozzle to a value comparable to the Venturi Tube, by increasing the size of the orifice or nozzle opening, also reduces the differential pressure at any given rate of flow and results in a decreased measuring range.

Example: 10-in. Herschel Standard Venturi Tube with 4-in. throat. Rate of flow 1,400 gallons per minute. $d_2/d_1 = 0.4$.

By following directions for Example 3 given on the Rate of Flow Alignment Diagram, Fig. V, we find differential head = 240 inches of water.

Loss of Head, Fig. IV, 11½% of 240 inches = 27.6 inches of water.

Assume that the average meter recording instrument will not respond accurately to changes in differential of less than .010 inches of water.

Minimum differential equals 1.00 inches for performance accuracy of 1% of differential.

Rate of flow varies as square root of differential.

$\therefore$ accurate measuring range of Venturi $= \sqrt{\frac{240}{1}} =$

15.5 to 1 or 1,400 to 90 G.P.M.

For same unrecoverable loss of head of 27.6 inches Orifice Plate opening would be 7.06 inches (approx.) or $d_2/d_1 = .7$.

Differential pressure for 1,400 G.P.M. = 53.4 inches of water.

Loss of Head (Fig. IV) = 51¾% of 53.4 inches of water = 27.6.

Accurate measuring range of Orifice Plate $= \sqrt{\frac{53.4}{1}} =$

7.3 to 1, about one-half that of Venturi.

Having now established briefly the characteristics of two principal differential producers, let us determine their practical significance by recourse to common problems met in water works practice.

Horsepower is measured in foot-pounds of work performed in a definite time period. If we raise a 50 pound weight a distance of one foot, the work done is 50 foot-pounds. By analogy, if we have 8,340 pounds of water (approximately 1,000 gals.) per minute flowing through a pipe line and one foot of head is lost by pipe friction, the result is the same as though the water had been raised one foot, or energy is being expended at a rate of 8,340 foot-pounds per minute.

Practical Problems

Two practical problems are cited to illustrate the method of determining the comparative cost of using Venturi Tubes and Orifice Plates.

Problem A

Water pumped through line containing 16 inch Herschel Standard Venturi Tube with 6½ inch throat.

Average rate, 3,700 G.P.M.

Electric-driven pump with over-all (wire to water) efficiency of 70%.

Average operating period 15 hours per day for 360 days per year.

Power cost 1½c per K.W.H.

$$d_2/d_1 = \frac{6.5}{16.0} = .405$$

Using Alignment Chart, Fig. V, Venturi differential = 240 inches = 20 feet of water.

From Fig. IV, corresponding friction loss = 11½% of 20 feet = 2.3 feet.

3,700 G.P.M. × 8.34 = 30,858 pounds.

Energy Loss = 30,858 × 2.3 = 70,973 foot-pounds per minute; and $\frac{70,973}{33,000} = 2.15$ horsepower.

Equivalent electrical loss = 2.15 × .746 = 1.605 kilowatts.

Corrected for motor and pump efficiency $\frac{1.605}{.70} = 2.29$ KW.

Cost of power per year = Hours × KW. Loss × Cost per K.W.H. = $(360 \times 15) \times (2.29) \times (.015) = \$185.00$

From Fig. V, an Orifice Plate for same maximum flow would have an opening 8.25 inches diameter.

$$d_2/d_1 = \frac{8.25}{16} = .515.$$

Loss through Orifice = 71% of differential = .71 × 20 = 14.20 feet.

$$\text{HP. Loss} = \frac{14.20}{2.3} \times 2.15 = 13.3.$$

$$\text{Cost of Power per year} = \frac{13.3}{2.15} \times \$185.00 = \$1,145.00.$$

Cost of 16 inch Venturi Tube	$640.00
Cost of 16 inch Orifice Plate and Flanges	65.00
Difference	$575.00

Saving in power consumption by using the Venturi Tube, $1,145.00 − $185.00 = $96.00 per year.

Omitting depreciation, $\frac{960}{575} = 167\%$ return on investment.

Conclusion: In comparison with the Orifice, the Venturi Tube would pay for itself in about six months and should be selected.

Problem B

Motor-driven pump operating 15 hours per day, 350 days per year = 5,250 hours per year.

Discharge line, 4.00 inches.

Wire to water efficiency, 60%.

Cost of power, 2c per K.W.H.

Pump discharge average rate, 100 G.P.M.

4.00 inch Venturi Meter designed for a maximum of 350 G.P.M.; throat diameter, 2.00 inch.

$$d_2/d_1 = \frac{2.00}{4.00} = .50.$$

Following the procedure outlined in "Problem A" and using Alignment Chart, Fig. V, differential pressure across the Venturi connections for 100 G.P.M. is 18¾ inches water.

From Fig. IV, friction loss = 10½% of 18¾ inches = 1.97 inches or .164 feet.

$$\text{H P. loss} = \frac{100 \times 8.34 \times .164}{33,000} = .00415.$$

Substituting an Orifice Plate for the Venturi Tube the 18¾ inches differential (Fig. V) gives Orifice opening of 2.49 inches

or $d_2/d_1 = \frac{2.49}{4.00} = .622.$

From Fig. IV, friction loss = 65.0% of 18¾ inches = 11.32 inches or .945 feet.

$$\text{H.P. loss} = \frac{.945}{.164} \times .00415 = .024.$$

.024 − .00415 = .0199 excess of H.P. loss of Orifice over Venturi.

.0199 × .746 = .0148 K.W.

Corrected for pump efficiency.

$$\frac{.0148}{60} = .0247 \text{ K.W.}$$

Difference in cost of power per year of operation = cost per K.W.H. × electrical loss × hours of operation = .0199 × .0247 × 5,250 = $2.58.

Cost of 4 inch × 2 inch Venturi Tube	$125.00
Cost ot Orifice Plate and Flanges	30.00
Difference	$ 95.00

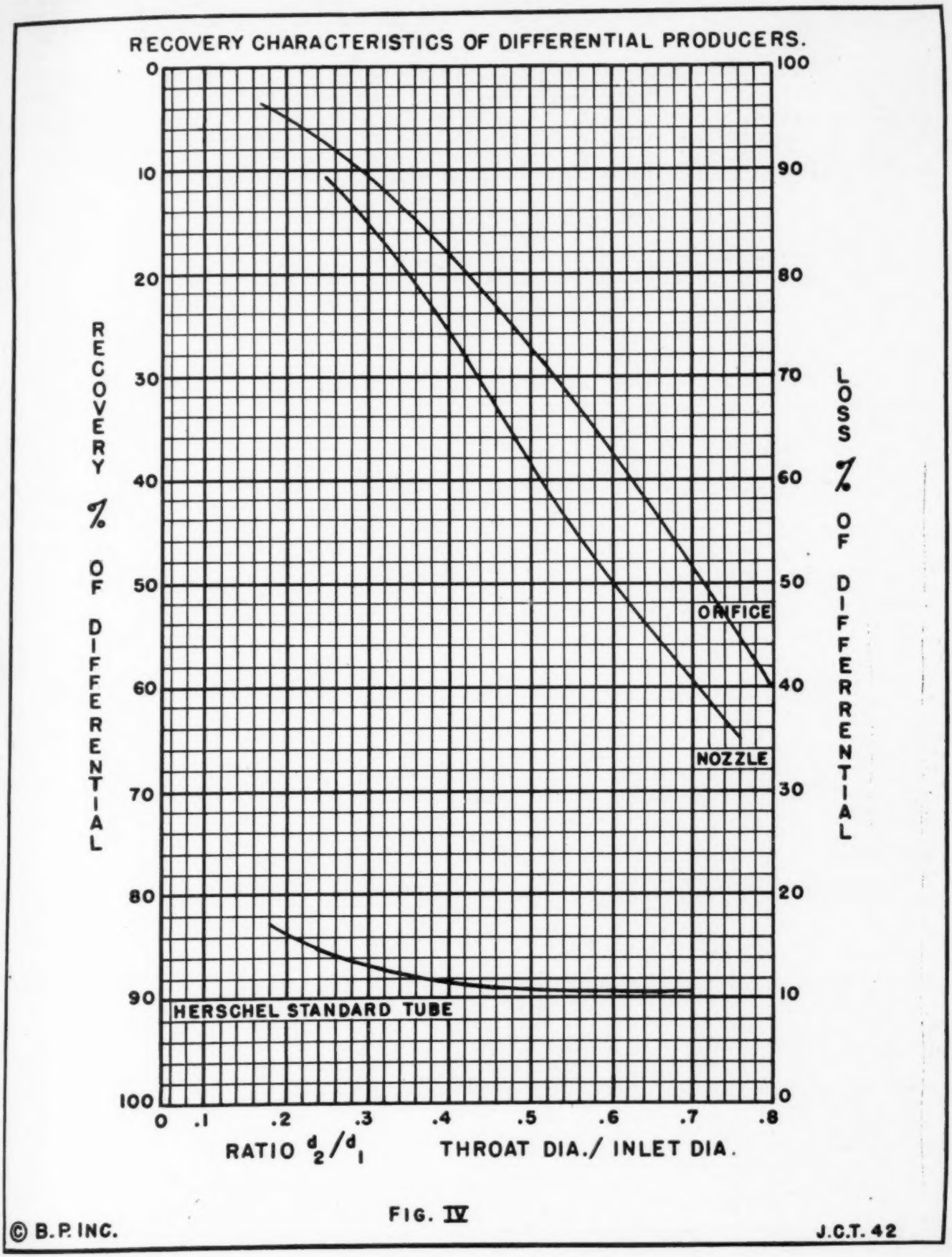


Fig. IV—Recovery Characteristics of the Venturi Tube, Nozzle and Orifice.

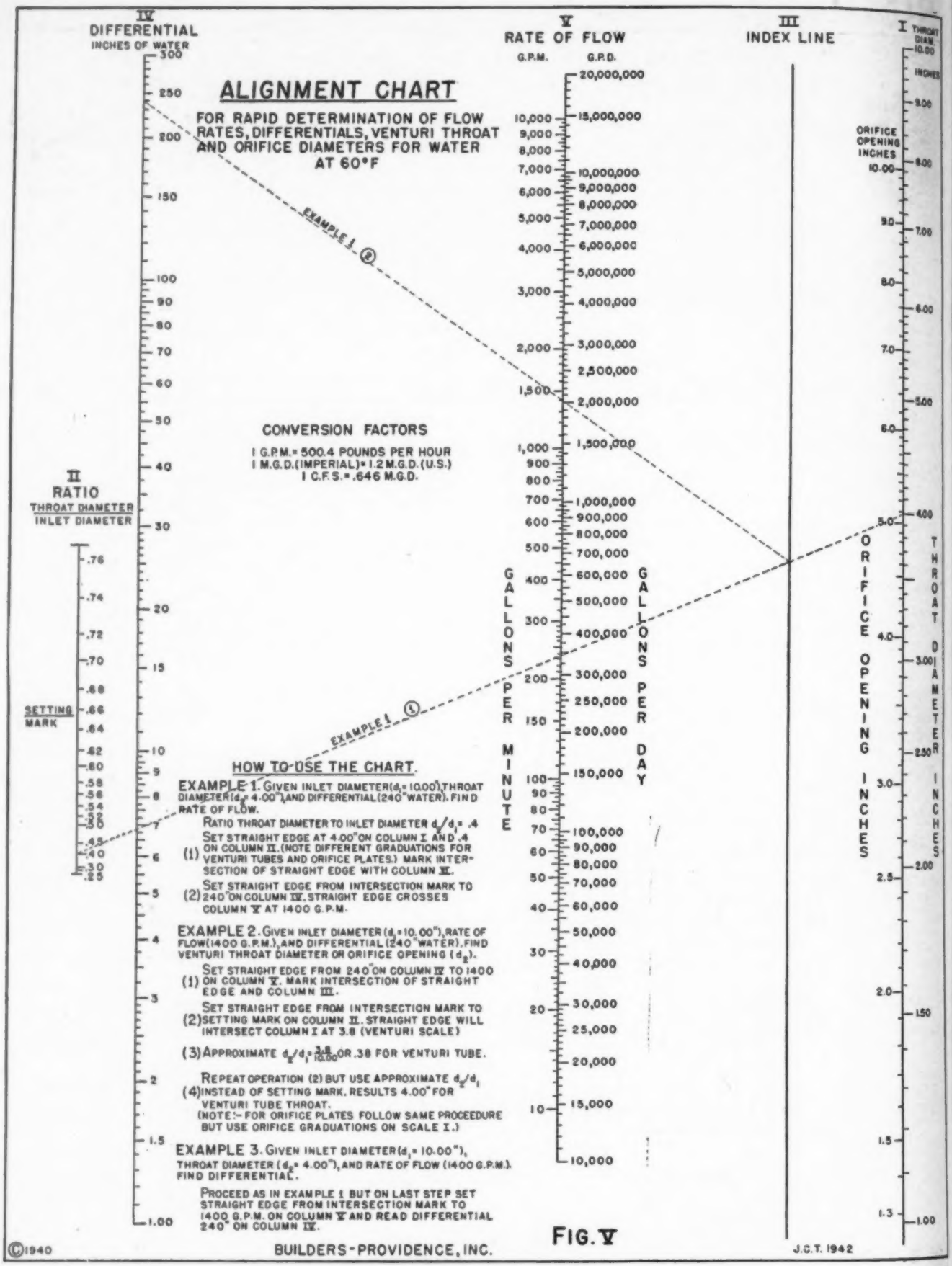

ALIGNMENT CHART
FOR RAPID DETERMINATION OF FLOW RATES, DIFFERENTIALS, VENTURI THROAT AND ORIFICE DIAMETERS FOR WATER AT 60°F
IV DIFFERENTIAL INCHES OF WATER
V RATE OF FLOW G.P.M. G.P.D.
III INDEX LINE
I THROAT DIAM. INCHES
ORIFICE OPENING INCHES
II RATIO THROAT DIAMETER / INLET DIAMETER
SETTING MARK
GALLONS PER MINUTE
GALLONS PER DAY
THROAT DIAMETER INCHES
ORIFICE OPENING INCHES
EXAMPLE 1
CONVERSION FACTORS
1 G.P.M. = 500.4 POUNDS PER HOUR
1 M.G.D. (IMPERIAL) = 1.2 M.G.D. (U.S.)
1 C.F.S. = .646 M.G.D.
HOW TO USE THE CHART.
EXAMPLE 1. GIVEN INLET DIAMETER (d_1 = 10.00"), THROAT DIAMETER (d_2 = 4.00"), AND DIFFERENTIAL (240" WATER). FIND RATE OF FLOW.
RATIO THROAT DIAMETER TO INLET DIAMETER d_2/d_1 = .4
(1) SET STRAIGHT EDGE AT 4.00" ON COLUMN I AND .4 ON COLUMN II. (NOTE DIFFERENT GRADUATIONS FOR VENTURI TUBES AND ORIFICE PLATES.) MARK INTERSECTION OF STRAIGHT EDGE WITH COLUMN III.
(2) SET STRAIGHT EDGE FROM INTERSECTION MARK TO 240" ON COLUMN IV. STRAIGHT EDGE CROSSES COLUMN V AT 1400 G.P.M.
EXAMPLE 2. GIVEN INLET DIAMETER (d_1 = 10.00"), RATE OF FLOW (1400 G.P.M.), AND DIFFERENTIAL (240" WATER). FIND VENTURI THROAT DIAMETER OR ORIFICE OPENING (d_2).
(1) SET STRAIGHT EDGE FROM 240" ON COLUMN IV TO 1400 ON COLUMN V. MARK INTERSECTION OF STRAIGHT EDGE AND COLUMN III.
(2) SET STRAIGHT EDGE FROM INTERSECTION MARK TO SETTING MARK ON COLUMN II. STRAIGHT EDGE WILL INTERSECT COLUMN I AT 3.8 (VENTURI SCALE)
(3) APPROXIMATE $d_2/d_1 = \frac{3.8}{10.00}$ OR .38 FOR VENTURI TUBE.
(4) REPEAT OPERATION (2) BUT USE APPROXIMATE d_2/d_1 INSTEAD OF SETTING MARK. RESULTS 4.00" FOR VENTURI TUBE THROAT.
(NOTE:- FOR ORIFICE PLATES FOLLOW SAME PROCEEDURE BUT USE ORIFICE GRADUATIONS ON SCALE I.)
EXAMPLE 3. GIVEN INLET DIAMETER (d_1 = 10.00"), THROAT DIAMETER (d_2 = 4.00"), AND RATE OF FLOW (1400 G.P.M.). FIND DIFFERENTIAL.
PROCEED AS IN EXAMPLE 1 BUT ON LAST STEP SET STRAIGHT EDGE FROM INTERSECTION MARK TO 1400 G.P.M. ON COLUMN V AND READ DIFFERENTIAL 240" ON COLUMN IV.
©1940
BUILDERS-PROVIDENCE, INC.
FIG. V
J.C.T. 1942

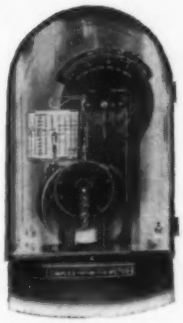
Fig. V—Chart for Rapid Determination of Flow Rates, Differentials, Venturi Throat and Orifice Diameters.

(Continued on page 53)

SIMPLEX VALVE & METER COMPANY

6743 UPLAND STREET, PHILADELPHIA 42, PENNSYLVANIA

SIMPLEX stands for LEADERSHIP in WATER WORKS & SEWAGE EQUIPMENT



TYPE MO METER

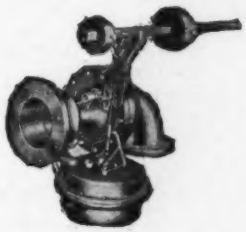
Indicates, records and totalizes fluid flow rates. Consistent high accuracy over wide flow range (up to 43 to 1); extreme sensitivity to every change in flow; simplicity of design, trouble-free operation, minimum maintenance cost. Evenly graduated, direct reading flow scale and chart. Floor stand, wall bracket or Panel Board mounting.

BULLETIN 300

TYPE MS FLOW RATE METER

Accurately indicates, records and totalizes flow rate. Bell-shaped float automatically extracts the square root of the law of flow and makes possible the direct reading chart —evening graduated from 0 to maximum. The arm of the recording pen connects directly with the float for inevitable accuracy of transcription and sensitivity to flow change.

BULLETIN 350



RATE OF FLOW CONTROLLERS

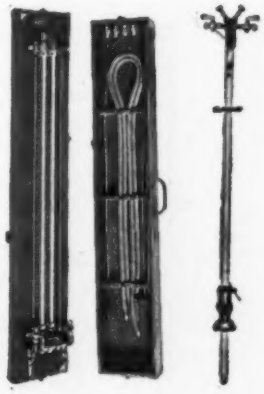
For gravity or pressure Filters, Clearwells, etc. A direct acting, balanced valve type controller, operated by a Venturi tube located in the effluent line. Lowest obtainable head losses when wide open; highest degree of accuracy without compensating mechanisms; largest possible ratio from maximum to minimum rates with any given size of unit; no electrical mechanisms used in operation. The controller starts quickly from a wide open position and takes the set rate in less than 15 seconds. Adapted to various types of clearwell control.

BULLETIN 250

AIR INLET VALVE

Eliminates the possibility of collapse of pipe line walls due to sudden drop in pressure in gravity flow line. The non-collapsible float is buoyed by the water in the line until a condition arises which tends to create a vacuum—then the buoying effect of the water is lost, the float drops from its seat, to admit air and destroy the vacuum.

BULLETIN 125



PITOT EQUIPMENT

Check the operating efficiency of distribution systems, pumps, meters. Panel board, portable, or stationary Recorders, manometers, and pitot tube types of equipment for accurate surveys—at low cost and with small expense—effect definite savings in operating loss.

BULLETIN 50

GAUGES

Indicating, recording, and/or totalizing gauges, strictly proportional to the Rate of Flow or Loss of Head. Mercury Float or Water Operated. Types for gauging Loss of Head, Rate of Flow, Depth, Elevation, Sand Expansion, etc. All Simplex Gauges are designed for accuracy, visibility, accessibility of moving parts, and reliability in service.

BULLETIN 170

AIR RELEASE VALVE

Automatically vents air obstructions that might otherwise cause operating loss or damage to pipe lines and pumps. Dependable in service. Simple construction—one lever movement operates a tight seating needle valve, actuated by a heavy glass ball float. Types for pressures up to 1250 lbs. per sq. in. — tested to several times the service working pressure.

BULLETIN 140

MO & MS METERS • CONTROLLERS • GAUGES • SAND EXPANSION INDICATORS • AIR RELEASE VALVES • AIR & VACUUM VALVES • PITOT EQUIPMENT • SUMMATORS • PRIMARY DEVICES (VENTURI TUBES, PITOT TUBES, ORIFICES, NOZZLES, WEIRS AND FLUMES)

BUILDERS-PROVIDENCE, INC.

DIVISION OF BUILDERS IRON FOUNDRY

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BUILDERS WATER AND SEWAGE WORKS Equipment

OVER 50 YEARS' EXPERIENCE AT YOUR SERVICE

Inquiries for recommendations covering the adaptation of standard metering and controlling devices are invited. Printed Bulletins, illustrating and describing equipment mentioned in these pages, are available on request.

VENTURI METERS

Metering the Flow of Water, Sewage, Sludge, or Air through Main Pipe Lines.

TYPE M, FLO-WATCH AND CHRONOFLO INSTRUMENTS

Metering the Flow of Water, Sewage, Sludge, Gas, or Air through Medium Sized and Small Lines, Open Channels, etc.

PROPELOFLO METERS

Totalizing flow meters of propeller type for main water line metering.

SIGHTFLO INDICATORS

Constant head-loss, variable area meters for water and sewage works applications.

HOOK LIGHT SAND EXPANSION GAUGE

Inexpensive, portable. Measures sand expansion with a light.

VENTURI CONTROLLERS

Effluent Rate, Wash Rate, Raw Sewage and Return Sewage.

FILTER GAUGES

Loss of Head, Rate of Flow, and Sand Expansion.

LIQUID LEVEL GAUGES

Settling Tanks, Filters, Clear Wells, Wash Tanks, Reservoirs, etc.

RATIO GAUGES

Air/Sludge and Return Sludge/Sewage.

KENNISON NOZZLES

Metering Open Flow of Sewage, Sludge and Trade Wastes.

CHRONOFLO TELEMETERS AND CONTROLLERS

Flow, Liquid Level, Pressure, Temperature, and Chemical Feed Proportioning.

TOLEDO-CHRONOFLO CONVEYOR SCALES

Weighing Sludge Cake in transit.

VENTURI TUBES

Fig. 1—Herschel Standard Venturi Tube

Fig. 2—VTS4 Venturi Tube

The Venturi Meter is recognized as the standard for measuring the flow of water, sewage and air in main pipe lines. It consists of the Venturi Tube (Figs. 1 and 2) installed in pipe line, and the Register-Indicator-Recorder or other instruments connected to the Tube by two small pressure pipes. The proportions and length of the Herschel Standard Venturi Tubes were selected by the inventor from extensive experimentation and are designed for a minimum pressure loss. This usually has a definite economic value since it lowers pumping costs. The VTS4 Venturi Tubes are shorter, somewhat lower in price, but throats are not as interchangeable and pressure loss is somewhat greater. Bulletin 143-A.

PROPELOFLO METER

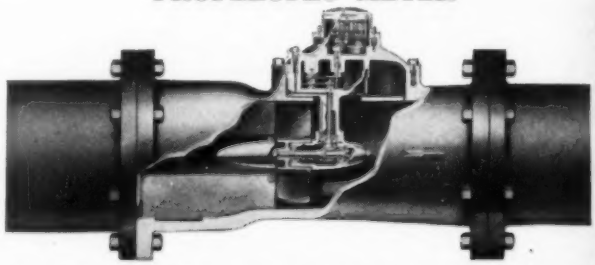


Fig. 3—Propeloflo Meter, flange mounted. Available also in saddle mounting and bell and spigot models

This new propeller type flow meter for main water line metering introduces many new features, including streamline Venturi design. The Venturi throat creates uniform, high velocity distribution of flow against full area of propeller, resulting in exceptional accuracy throughout a wide range.

An 8-blade plastic propeller transmits rotation through bevel gears to direct-reading counter with ample power to drive indicating and recording devices or for proportioning chemical feeders. Propeller hub, bracket and nose are streamlined, reducing loss in head to not over one-half foot of water at normal maximum flow. Installation is simple and maintenance easy. Bulletin 350.

BAROMETRIC MERCURY MANOMETER, MODEL MAB is a simple, yet accurate, flow rate indicator with scale graduated directly in flow units; used with any type differential producer. Bulletin 343.

TYPE M REGISTER-INDICATOR-RECORDER

A popular instrument having the advantage of unusual sturdiness, durability, and accuracy; furnishes three distinct kinds of information: an indication of the momentary flow through the Venturi Tube; a permanent record of this rate shown upon a 12" circular chart; the total quantity on a 3½" counter dial; all dials graduated in direct reading units for the particular Venturi Tube with which it is to be used. Bulletin 324.

Fig. 4.—Type M Register-Indicator-Recorder

VENTURI FILTER CONTROLLER

Fig. 5 — Model RCE Direct Acting Controller

Since Builders manufactured the first Venturi Filter Controller many years ago, Venturi Controllers have become standard equipment in filtration plants. Several types of controllers are offered, each type designed to serve particular conditions, automatically maintaining constant flow rate through the filter bed.

THE MODEL RCE DIRECT ACTING CONTROLLER

(Fig. 5) Features smooth, unwavering control; low loss of head; sturdy, balanced valve; compact design; powerful "floating piston" actuation and exclusive molded tapered piston seal. All rotating bearings of the Model RCE Controller are antifriction bearings. Bulletin 321-A.

THE MODELS RCA AND RCB CONTROLLERS

Are hydraulically operated. Model RCA has a control valve of the gate type with specially shaped port; Model RCB has a two-butterfly valve and is used on larger effluent lines. Bulletin 325.

WASH WATER CONTROLLERS, MANUAL MASTER CONTROLLERS AND CLEARWELL MASTER CONTROLLERS also are available—information on request.

FILTER GAUGES

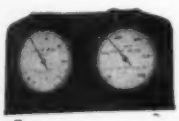


Fig. 6—Rate of Flow and Loss of Head Gauge

Builders Filter Gauges are the result of nearly a half-century's experience in designing and manufacturing such instruments for hundreds of plants. Reduced to simplest mechanical elements, these gauges are styled and finished to enhance the attractiveness of modern filtration plant interiors. Bulletin 329.

RATE OF FLOW AND LOSS OF HEAD GAUGES are usually mounted on the operating table convenient to valve controls, but can be mounted on self-supporting floor stands where desirable. The indicator and chart display information gathered by the accurate, dependable Builders Diaphragm Pendulum Units which have earned emphatic approval of water works engineers after more than a decade of service under all sorts of conditions.

HOOK LIGHT SAND EXPANSION GAUGE

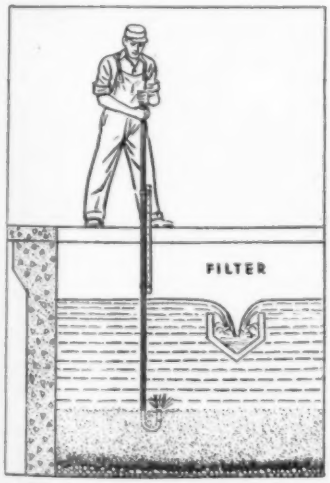


Fig. 7—Method of using Hook Light Sand Expansion Gauge

A novel and accurate means for determining sand expansion with a light during back washing of filter beds. Amount of expansion is read directly on scale without reference to water temperature or size of sand grains; duplicate readings within 1/16" can be consistently obtained. The Hook Light is inexpensive and entirely portable. Buleltin 348.

WATER LEVEL GAUGES are used for indicating and/or recording water level in basins, tanks, and reservoirs; operated by spherical copper float in a pipe or well. Indicator dials and charts are graduated to read in feet of depth, elevation or other units.

Fig. 8—Large Dial Gauge.

BUILDERS LARGE DIAL ILLUMINATED GAUGES, available in 24" and 30" sizes with single or double faces for wall or ceiling mounting, are commonly used in water works to make readings visible to the operator from a distance. Concealed double hinges, a patented feature, allow acceess to the mechanism without removal from mounting. Indirect white gas-tube illumination gives a pleasing soft glow uniformly around entire dial circumference.

KENNISON NOZZLES

Accurately measure flow through partially filled pipes and open channels where there is wide range in flow rates. This device is particularly successful on measurement of raw sewage, sludge and trade waste; available in size 6" to 36"; used with instruments shown below. Bulletin 334A.

Fig. 9—Kennison Nozzle for Open Flow

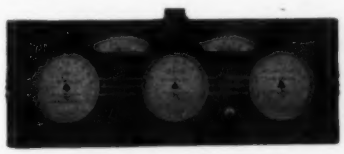


Fig. 10—Five-Dial Ratio Gauge

RATIO INDICATING GAUGES are especially useful in sewage plant operation and enable operator to maintain predetermined ratio of flow rates between air/sewage, air/sludge, etc. Bulletin 329.

FLO-WATCH

A small, medium-priced mechanical instrument universally applicable for use with Venturi Tubes, Nozzles, Orifice Plates, and Weirs: available in a variety of mountings and dial combinations. Bulletin 318A.

Fig. 11—Flo-Watch Totalizer-Indicator-Recorder

CHRONOFLO TELEMETERS

Fig. 12—Chronoflo Receiver

Since their introduction a decade ago, Chronoflo Telemeters have found broad application in water and sewage plant service in bringing to a central operating point, from widely scattered locations, accurate records of flow, level, pressure, temperature, gate position, and weight. Chronoflo Transmitters are electrically connected by a simple two-wire circuit to Chronoflo Receiving Instruments. Automatic proportional control of Chemical Feeders in step with rate of flow is accomplished by a simple attachment to a standard Chronoflo Transmitter.

SIGHTFLO FLUSHING WATER INDICATOR

A rate of flow instrument designed as a guide in maintaining normal flushing rates. The Indicator is a constant head-loss variable area meter and indicates at a glance the flow of clear water into the taps or annular chambers of differential-operated Meters. Bulletin 347.

Fig. 13—Sightflo Flushing Water Indicator

BAILEY METER COMPANY

1072 Ivanhoe Road, CLEVELAND, OHIO

BOSTON CHICAGO NEW YORK MILWAUKEE PHILADELPHIA ST. PAUL BUFFALO KANSAS CITY PITTSBURGH HOUSTON CINCINNATI DENVER LOS ANGELES ATLANTA SEATTLE DETROIT SAN FRANCISCO

BAILEY METER COMPANY LIMITED, Montreal, Canada

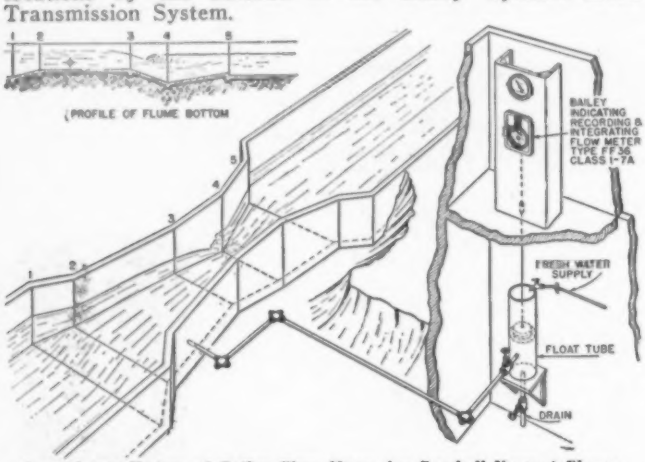
METERS, GAGES and CONTROLLERS for SEWAGE TREATMENT and WATER SUPPLY

STANDARD BAILEY REGISTERS

Bailey Flume Meters—Simplicity of installation, low head losses and self-cleaning features of the Parshall Flume have resulted in a greatly increased use of this device for a measurement of Sewage Flow in open channels.

The Bailey Flume Meter is simple and accurate. As shown in the attached illustration, it consists of a single float which is connected by a flexible cable to the sturdy recording, integrating and indicating mechanism on the panel board. The panel board may be omitted if desired and the recording mechanism mounted on a wall or column. This device may be adapted to any type of open channel metering over any operating range required. Its capacity can be altered in the field by installing new gears and/or cam without disturbing any other parts of the installation.

Standard Bailey Indicating, recording and integrating instruments are used, charts are 12 inches in diameter and uniformly graduated. Instruments may be placed in remote locations by the addition of the Bailey Synchro-Meter Transmission System.


1 2 3 4 5
PROFILE OF FLUME BOTTOM
BAILEY INDICATING RECORDING & INTEGRATING FLOW METER TYPE FF 36 CLASS I-7A
FRESH WATER SUPPLY
FLOAT TUBE
DRAIN

Typical installation of Bailey Flow Meter for Parshall Venturi Flume.

Bailey Weir Meters—For measuring flow using any type of Weir notch, highly accurate results can be obtained with a Bailey Weir Meter. This meter is similar to the Bailey Flume Meter and possesses the same features of sturdiness, flexibility and accuracy. Remote transmission can be provided when desired.

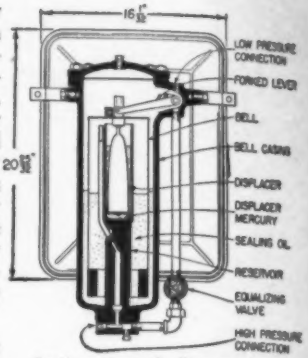
Open Float Type Meters—The Bailey Float Type Meter is especially adapted to measure the flow of sewage, sludge, dirty water or other liquids in pipe lines using a Venturi Tube, flow nozzle or eccentric orifice.

This meter is operated through a differential gearing and cam mechanism from floats which rest on the liquid surfaces in float tubes. It is similar in external appearance to Bailey Flume Meters.

Bailey Fluid Meter—The flow of steam, liquids and gases in pipe lines at high or low pressures can be accurately measured by the Bailey Fluid Meter. A Venturi Tube, flow nozzle, or orifice is used as the differential producing device and the meter indicates, records and integrates on the standard Bailey register previously described. Remote recorders may be provided by Bailey Synchro-Meter transmission which operates electrically on alternating current.

In addition to the rate of flow, this meter may also record pressure, temperature or liquid level on the same chart.

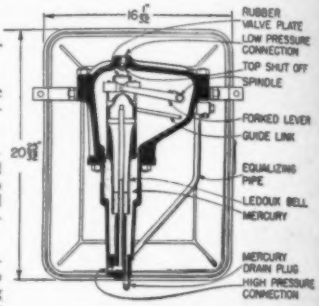
Described in bulletin No. 201-A.



Section through flow mechanism of Air Meter

Air Meters—These meters measure Air Flow in main lines and in individual lines to aeration tanks.

The register is similar in appearance to the Ledoux bell type, and the flow mechanism is designed to operate on a maximum differential pressure of 8-in. of water. *Described in bulletin No.* 301A.



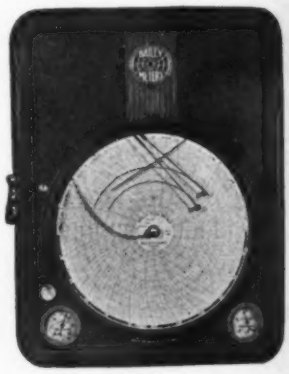
Section through flow mechanism of Ledoux Bell type Register.

Remote Registers — Bailey Telemetering systems make it possible to operate remote indicating, recording or integrating registers, which may be installed at a distance from the direct connected unit. These registers may measure flow in individual lines, total flow, liquid level, pressure and other factors.

Venturi Tubes—Standard Bailey Designs include a complete range of Venturi tubes and other primary elements suited to the measurement of sewage, sludge and water. The selection of a suitable primary element is governed by such factors as capacity required, type of flanges, pressure loss allowable and character of fluid to be metered.

Controllers—Bailey Controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level. They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey gages and registers.

Bailey control is fully automatic, dependable and exceptionally flexible.



Bailey Recorder—Controller.

Bailey Registers measuring Sewage, Sludge and Air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

(Continued from page 48)

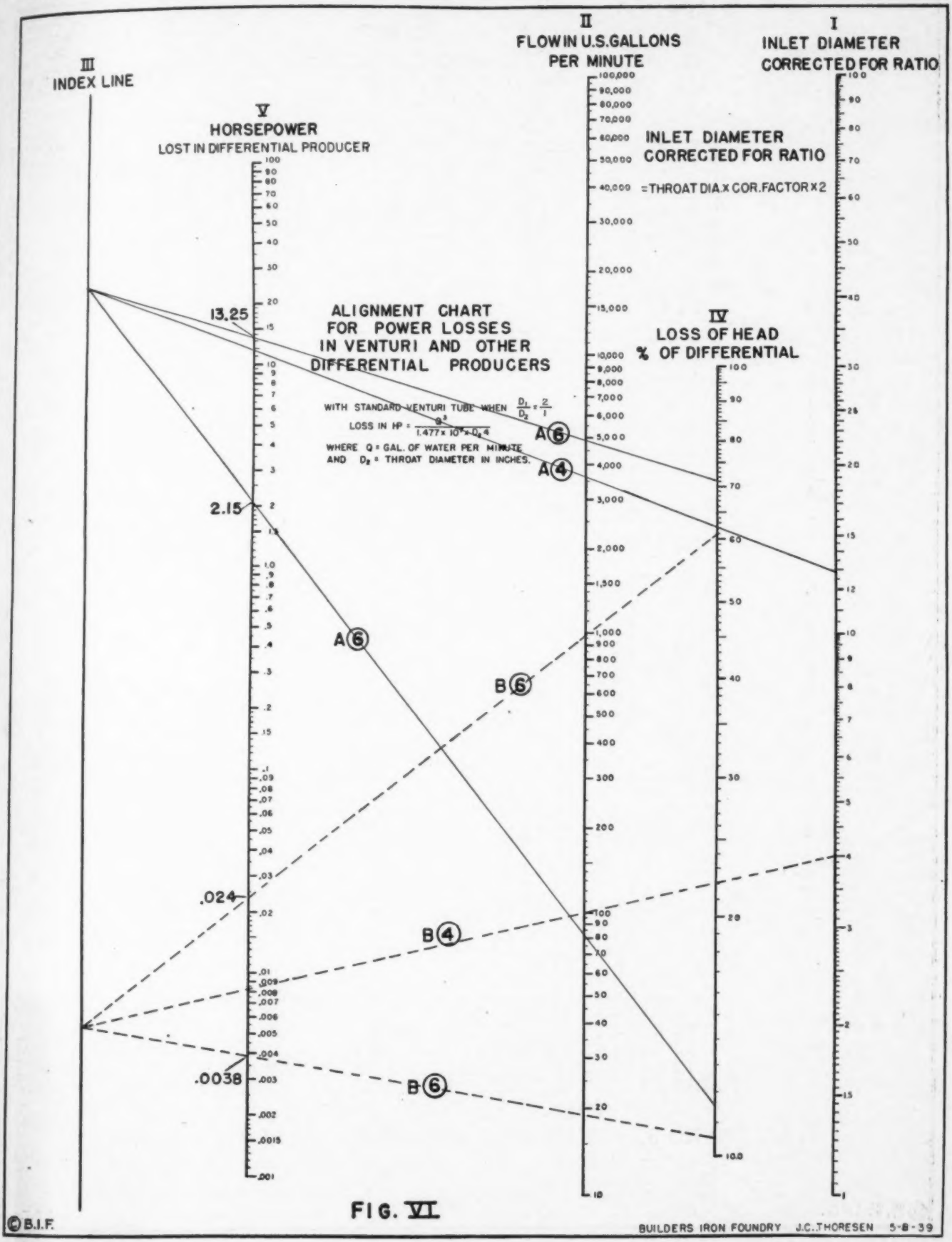


Fig. VI—Chart for Power Losses Through Venturi Tubes and Other Differential Producers.

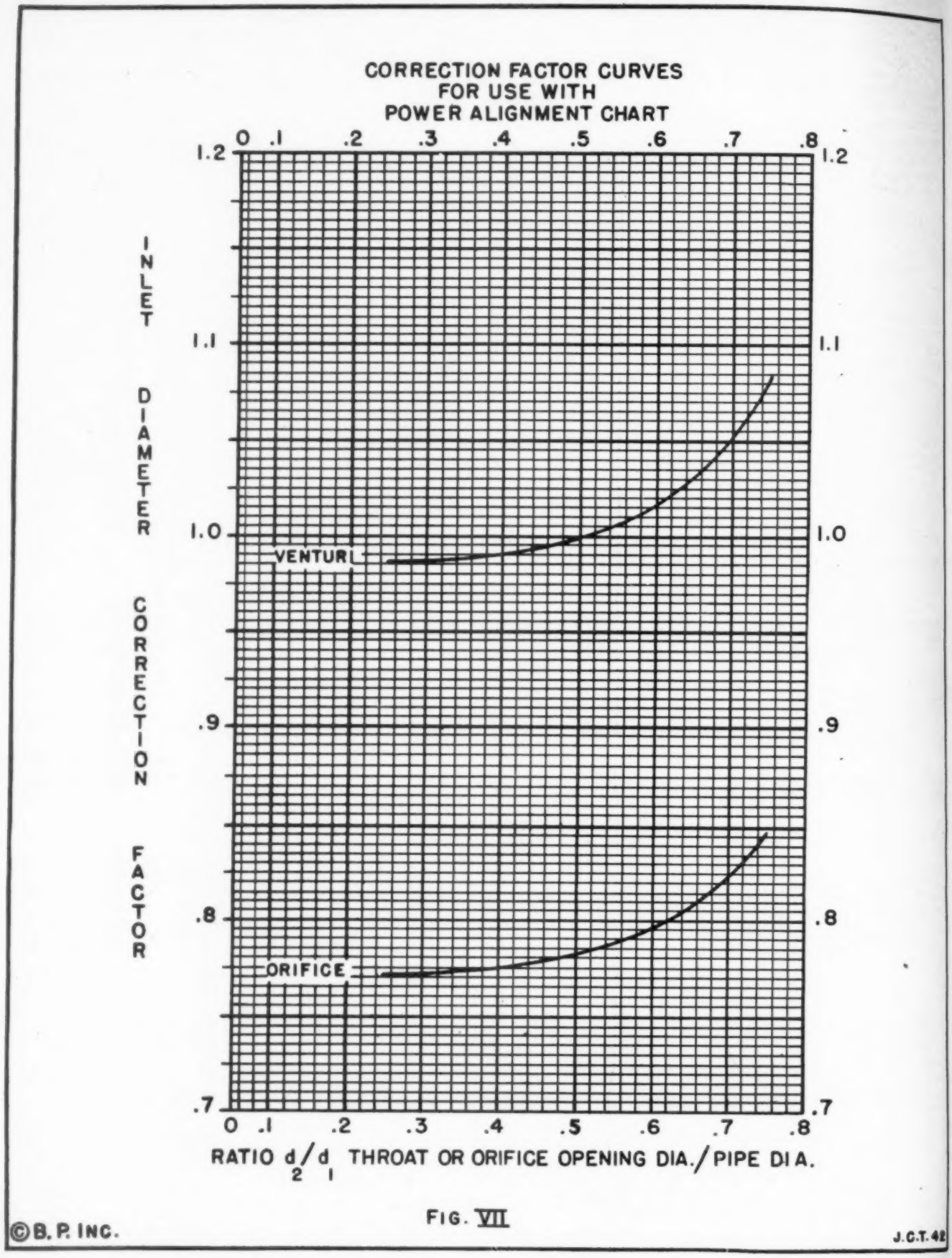


Fig. VII—Correction Factor Curves. (For use with Alignment Chart for Power Losses—Fig. VI.)

Conclusion: On the basis of a saving of power of only $2.58 per year, it is readily apparent that it will take 36 years to pay the increased cost of the Venturi Tube, and therefore, from a monetary viewpoint, the Orifice Plate should be selected.

To simplify the calculations needed for any meter installation a Horsepower Alignment Chart (Fig. VI) has been prepared. It is easily used and the results are accurate to within a few per cent. Its application to the two problems calculated in the preceding paragraphs is illustrated:

Problem A

16 inch × 6½ inch Venturi Tube compared with 16 inch Orifice Plate having 8.25 inch opening.

Flow Rate, 3,700 G.P.M.

(1) For the Venturi Tube $d_2/d_1 = \frac{6.5}{16.0} = .406$

For the Orifice Plate $d_2/d_1 = \frac{8.25}{16.0} = .515$

(2) From Fig. VII, "Correction Factor" for the Venturi Tube is .992; for the Orifice Plate .783.

(3) To obtain the "Inlet Diameter Corrected for Ratio" for the Venturi Tube or Orifice, multiply the throat diameter or Orifice opening by correction factor × 2. For the Venturi Tube, 6.2 × .992 × 2 = 12.89. For the Orifice Plate 8.23 × .78 × 2 = 12.88. Theoretically, these two products should be exactly the same; their close agreement checks the accuracy of the work.

(4) From the point 12.89 on the Corrected Inlet Diameter Scale (I) draw a straight line through 3,700 G.P.M. on Rate of Flow Scale II. Extend this line until it intersects the Index Line.

(5) From the "Recovery Characteristics" Chart, Fig. IV, the friction loss of a Venturi Tube with d_2/d_1 ratio of .406 is 11.5% of differential; for the Orifice Plate with d_2/d_1 ratio of .515 it is 71%.

(6) From the point previously located on Index Line III of Alignment Chart, draw two lines, one to the 11.5% point on the Loss of Head Per Cent of Differential Scale IV; the other to the 71% point on the same scale.

(7) These two lines cross the Horsepower Scale V and the points of intersection represent the horsepower loss for the Venturi Tube and Orifice, respectively 2.15 and 13.25.

(8) The difference in cost of operation of the two differential producers can be quickly determined by using the following simplified formula:

Excess cost of using Orifice Plate over Venturi Tube

$$= \frac{(HP_o - HP_v) \times K \times T \times C}{E}$$

In which:

HP_o = Horsepower Loss for Orifice Plate

HP_v = Horsepower Loss for Venturi Tube

K = Conversion Factor, HP to KW = .746

T = Total hours of operation

C = Cost of Power per KWH

E = Wire to water efficiency of pumping unit (motor and pump) usually 50% to 80%.

Substituting the values in Problem A

Excess cost of Orifice

$$= \frac{(13.25 - 2.15) \times .746 \times (3600 \times 15) \times .015}{.70} = \$962.00$$

This corresponds almost exactly with the previously calculated difference in cost of $1,145 — $185 = $960.00.

Problem B

4.0 inch × 2.0 inch Venturi Tube compared with Orifice having 2.49 inch opening. Flow rate 100 G.P.M.

(1) For the Venturi Tube $d_2/d_1 = \frac{2.0}{4.0} = 0.5.$

For the Orifice

$$d_2/d_1 = \frac{2.49}{4.00} = .622$$

(2) From Correction Factor Chart (Fig. VII) correction factor for Venturi Tube is 1.00 and for Orifice Plate .80.

(3) Inlet diameter corrected for ratio: Venturi Tube 2.0 × 1.00 × 2 = 4; Orifice Plate 2.49 × .80 × 2 = 4.

(4) From point 4 on Corrected Inlet Diameter Scale I, draw a line through the 100 mark on the Rate of Flow Scale II. Extend this to the Index Line III.

(5) From Chart, Fig. IV, friction loss of a Venturi Tube with d_2/d_1 ratio of .50 is 10½% of the differential; for an Orifice Plate with a d_2/d_1 ratio of .622 it is 60.5%.

(6) From the point previously located on Index Line III, of Alignment Chart, draw two lines, one to the 10.5% point on the loss of Head Per Cent of Differential Scale IV and the other to the 60.5% point.

(7) The points of intersection of these two lines with the Horsepower Scale represent the horsepower loss for the Venturi Tube and Orifice, respectively, .0038 and .024.

(8) Difference in cost of operation

$$= \frac{(HP_o - HP_v) \times K \times T \times C}{E}$$

$$= \frac{(.024 - .0039) \times .746 \times 5250 \times .02}{.60} = \$2.63$$

This solution by use of the diagrams agrees very closely with the calculated figure of $2.60.

Following the procedure as outlined and with the aid of the several diagrams presented anyone, after a little preliminary practice, can by their use quickly determine the most economical type of meter for any installation under consideration.

LAND MEASURE

A Quarter Section of 160 Acres Divided to Show Relationship of Rods, Chains and Feet

A rod is 16½ feet.

A chain is 66 feet or 4 rods.

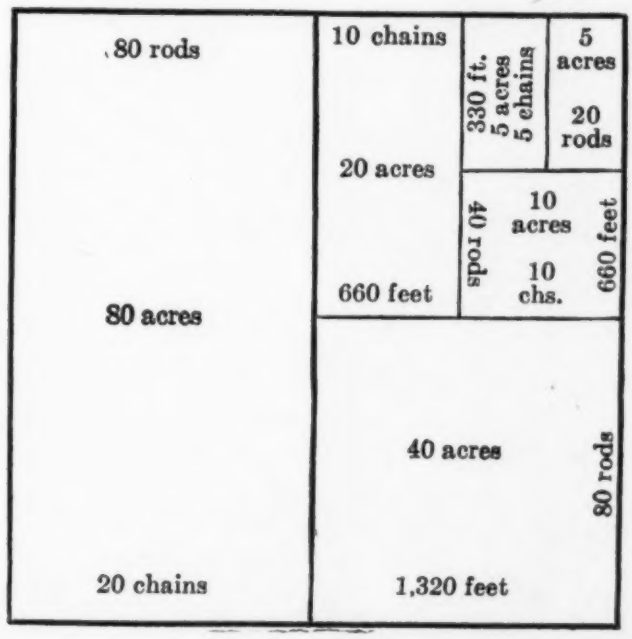
A mile is 320 rods, 80 chains or 5,280 ft.

A square rod is 272¼ square feet.

An acre contains 43,560 square feet.

An acre contains 160 square rods.

An acre is about 208¾ feet square.



THE DEMING COMPANY

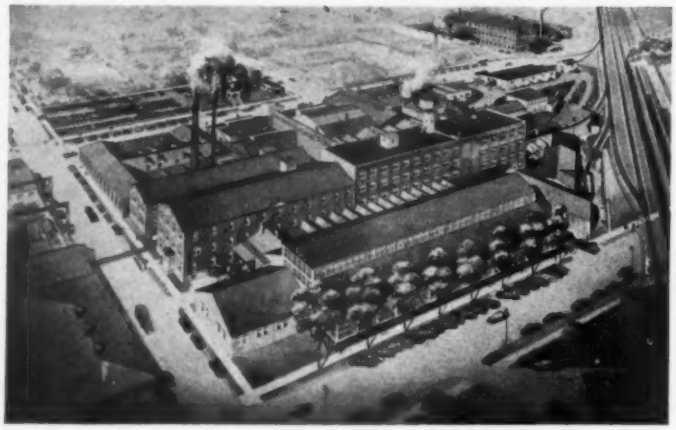
ESTABLISHED 1880

SALEM, OHIO, U. S. A.

DEMING PUMPS
FOR WATER WORKS AND SEWERAGE

(Following listings appear in "Classified Index of Products" in this publication).

BOILER FEED PUMPS
CELLAR DRAINERS
CENTRIFUGAL PUMPS
CONDENSATION PUMPS
DEEP WELL PUMPS
DIAPHRAGM PUMPS
DRAINAGE PUMPS
PORTABLE PUMPS



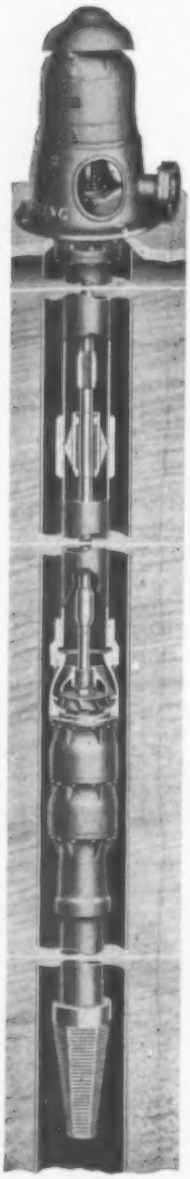
Group of Factory Buildings of The Deming Company, Salem, Ohio.

DEMING PUMPS
FOR WATER WORKS AND SEWERAGE

(Following listings appear in "Classified Index of Products" in this publication).

ROTARY PUMPS
SELF PRIMING PUMPS
SEWAGE PUMPS
SLUDGE PUMPS
SUCTION AND FORCE PUMPS
SUMP PUMPS
TURBINE PUMPS

Deep Well Turbine Pumps



These *water lubricated* deep well turbine pumps are designed to deliver capacities ranging from 15 to 3,000 gallons per hour and are widely used for municipal water supply, drainage, irrigation, swimming pools, etc.

The multi-stage vertical centrifugal pump construction allows the pumping unit to be placed at any depth from the surface, preferably submerged at all times.

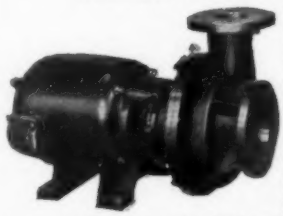
Vertical hollow-shaft motors are standard construction although other types of heads can be supplied such as belted drive heads, gear increaser heads, steam turbine heads, flexible coupling, or combination type heads.

Features of Deming Deep Well Turbine Pumps include semi-open, adjustable type impellers held in place with split tapered compression sleeves; Goodrich cutless rubber bearings of the fluted type are used in each bowl, or stage, and at a maximum interval of 10 feet in the column pipe. These bearings are thoroughly flooded and lubricated by the water being pumped. Stuffing box in the discharge head can be easily adjusted or repacked from ground level.

For complete information on Deming Deep Well Turbine Pumps, write for BULLETIN 4700-8.

Centrifugal Pumps

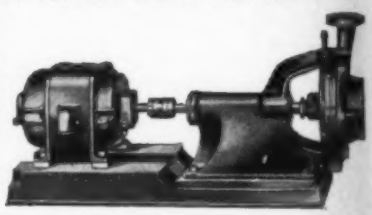
"MOTOR MOUNT" CENTRIFUGAL PUMPS



Compact, dependable units, Deming "MOTOR MOUNT" Pumps combine high efficiency and simplicity at moderate cost. There are 63 units in the line. Capacities range from 5 to 650 gallons per minute against heads from 10 to 85 feet. Features include semi-enclosed, three-vane impeller with non-overload characteristics; adjustable for capacity, head, clearance and wear. Motor is drip proof type, with moisture resisting insulation. Deep groove, over-size ball bearings. Fan ventilation.

Complete data in BULLETIN 4301. Write for copy

SIDE SUCTION CENTRIFUGAL PUMPS



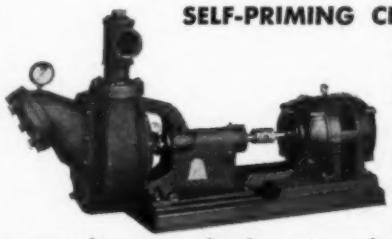
Standardized in design, Deming Side Suction Ball Bearing Centrifugal Pumps eliminate the need for expensive, specially designed equipment for a wide scope of pumping requirements.

There are 21 pumps in the line. Sizes range from 1 to 10 inches. Capacities range from 10 to 3,600 gallons per minute against heads up to 260 feet.

Deming Side Suction Centrifugal Pumps can be furnished for belt drive, electric motor, or gasoline engine drive.

Complete data in BULLETIN 4200. Write for copy

SELF-PRIMING CENTRIFUGAL PUMPS



These electric motor-driven units are designed for sump pump service with float switch control. Also used for cleansing swimming pools, core sucking service in ice plants, etc. Priming operations completely automatic. Semi-enclosed, non-clogging impeller.

Pumps can be furnished direct connected through flexible couplings; or to electric motors; or gasoline engines; or with pulley for belt drive.

Capacities range from 600 to 18,000 gallons per hour.

Complete data in BULLETIN 3000. Write for copy

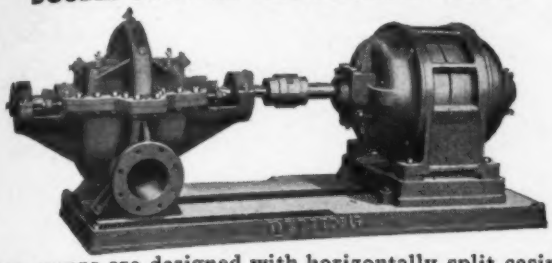
THE DEMING COMPANY

ESTABLISHED 1880

SALEM, OHIO, U. S. A.

Centrifugal Pumps

DOUBLE SUCTION CENTRIFUGAL PUMPS



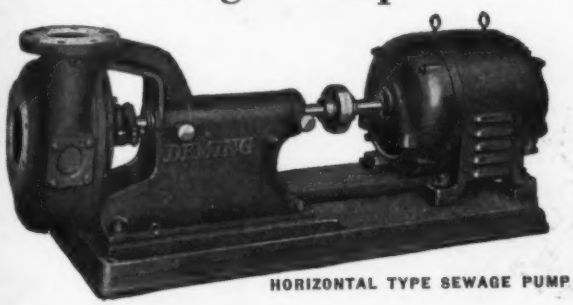
These pumps are designed with horizontally split casing. All features conform to latest engineering practice to obtain maximum efficiency for this type of unit. Recommended for working pressures up to 200 pounds.

Heavy ball bearings at each end of shaft take all lateral and end thrust. Rotating elements are in perfect static and dynamic balance, assuring a vibrationless pump at all speeds.

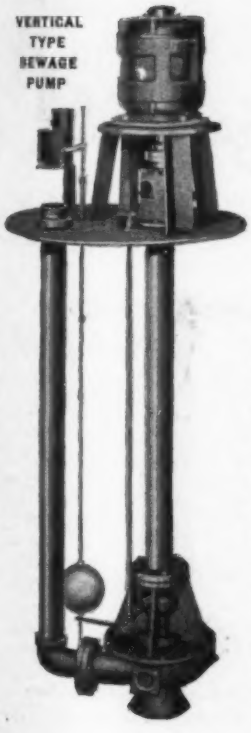
The line includes a wide range of sizes from 1½ to 10 inches with capacities up to 5,000 gallons per minute against heads up to 350 feet.

Complete data in BULLETIN 5003. Write for copy

Sewage Pumps



HORIZONTAL TYPE SEWAGE PUMP



VERTICAL TYPE SEWAGE PUMP

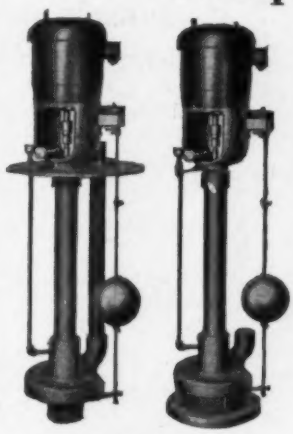
Deming non-clogging horizontal and vertical type sewage pumps are designed to handle safely and efficiently raw, unscreened sewage, storm water disposal, drainage, or other pumping requirements where liquids carrying along refuse, dirt, silt, rags, sticks, and stones must be handled with minimum danger from clogging, breakage, or undue wear.

These pumps are used in Sewage Disposal Plants, Paper Mills, Quarries, etc., and are suitable for many applications where standard Centrifugal Pumps are not designed for the indicated requirements.

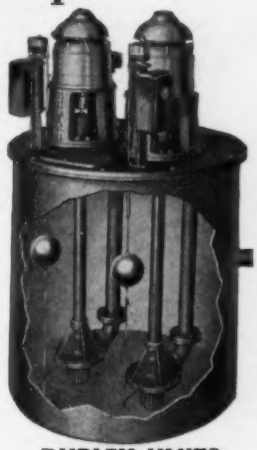
Deming Sewage Pumps are built in horizontal and vertical types for capacities from 60 to 1,200 gallons per minute and for heads not to exceed 80 feet.

As these pumps usually require individual engineering, a complete statement of conditions should accompany each inquiry.

Sump Pumps



SUMP PUMPS



DUPLEX UNITS

Deming Sump Pumps are designed in various types in a wide range of capacities from 10 to 3,200 gallons per minute with heads up to 120 feet and speeds from 860 to 1,750 r.p.m. for motor drive.

Construction of Deming Sump Pumps offers many important features including: (1) Impeller adjustable for capacity, head and wear; (2) Impeller fitted to shaft with taper, key and nut; (3) Full weight column pipe with precision thread; (4) Double length bottom shaft bearing with large grease chamber.

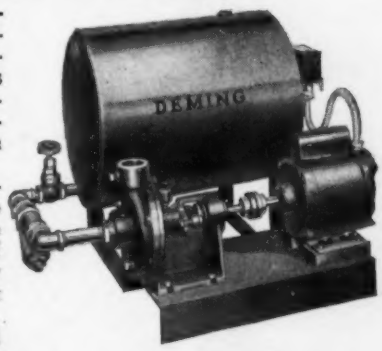
Deming Sump Pumps are furnished either in SINGLE or DUPLEX units of either wet or dry pit type. Can be installed in pits of every description wherever water collects and has to be emptied into sewer lines at a higher level or delivered above ground.

Duplex units meet requirements where extra precautions must be taken to insure uninterrupted service.

The complete line of Deming Sump Pumps is illustrated and described in detail in BULLETIN 4603. Write for copy

Condensation Return Units

DEMING 401ORC UNIT



Deming pump and receiver units are designed to return, automatically, to boilers the hot water of condensation from radiators, coils, and steam operated machinery. Condensate is automatically returned to the boiler by the pump, operation of which is controlled by an enclosed float switch.

Units are equipped with horizontal reciprocating pumps or side suction centrifugal pumps, depending upon capacity, pressure, and most efficient operation.

Receiver tanks are of extra heavy welded boiler plate. Tanks furnished with water gauge glass and with petcock and check valve in top, as illustrated.

Motors are furnished single phase, 2 or 3 phase, or direct current as specified. All units are equipped with motor protective device and are completely assembled and wired.

CAPACITIES: 79 units in the line cover a range of pump capacities from 2.25 gallons per minute to 60 gallons per minute. Write for complete information, which includes performance table of capacities, pressures, and other data.

RENSSELAER VALVE CO., TROY, NEW YORK

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ATLANTA, GA., Rhodes-Haverty Building
CHICAGO, ILL., Monadnock Building
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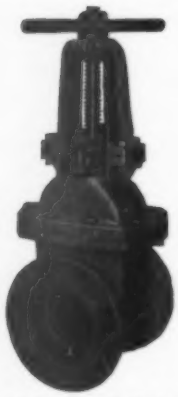
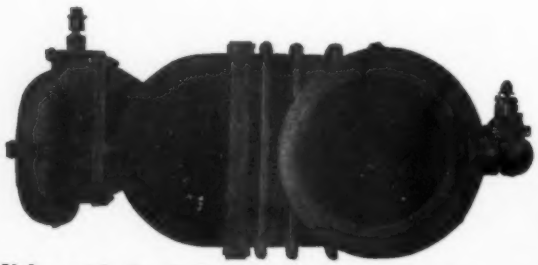
(Mr. J. S. Ten Eyck)
OKLAHOMA CITY, OKLA., Braniff Building
(Mr. E. J. Connelly)

Please address all inquiries to nearest Branch Office or Representative



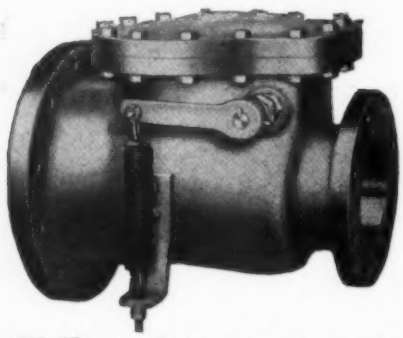
Outside Screw and Yoke Valve.



Valve with Bevel Gearing, Grease Case and By-pass.

Tapping Sleeve and Valve.

Rensselaer List 90A Fire Hydrant.



List 340 Clearway Quiet Closing Check Valve.

Fig 372 Air and Vacuum and Air Release Valve with Cut-off Valve.

Hydraulically Operated Valve with Square Bottom construction.

OS&Y-Valve with Motor Operating Unit, Mechanical Position Indicator and Stem Cover.

Motor Operated Floor Stand with Integral Control Equipment.

Floor Stand with Ball Bearings, Grease Fittings and Indicator.

NOTE: *We also make many other types and sizes of valves and accessory equipment. Please write for information.*

CENTRIFUGAL PUMPS*

Some Notes on Selection of the Proper Pump and A Simple Method of Checking Pump Efficiencies

By H. E. BECKWITH, Engineer
The Pitometer Company
New York, N. Y.

SOME twenty years ago when I first entered the water works field steam driven displacement type pumps were in general use. But, today we find the great majority of pumping stations equipped with electrically driven centrifugal pumps, with an occasional Diesel driven or turbine driven centrifugal installation. The old slow moving reciprocating pump of yesterday could always be depended upon to take care of changing pumping loads and varying heads without any great loss in efficiency. But, this is decidedly not so with the modern centrifugal pump, designed to work under rather fixed conditions. Any appreciable variation from these conditions is accompanied by a falling off in efficiency, which may be rather marked.

Unfortunately, the non-technical water works operator who got his early practical experience with the old displacement type of pump has not always become sufficiently acquainted with the characteristics of the centrifugal pump. Only too often the only demand made on a centrifugal pump is that it pump water, and little or no attention is paid to the efficiency with which it does its work. In fact the average water works man is usually not acquainted with any simple method of determining this efficiency.

It is, therefore, the purpose of this article to point out the conditions which may be expected to cause low operating efficiency, and to outline a simple method for testing the wire-to-water efficiency which gives results as close as is necessary in practical water works operation.

Basic Principles of the Centrifugal

As a youngster I used to tie a chestnut on the end of a string and whirl it around my head until I had imparted to it the force necessary to take it flying through the air at high speed. You did it, too. The principle of building up velocity of that chestnut by whirling it about the head is the same principle which is used in the design of a centrifugal pump. The water which enters the pump through the suction inlet is seized by the rotating vanes of the impeller and spun until it is rotating at terrific velocity. Since pressure and not velocity is desired, the pump is so designed that by gradually slowing down this velocity in the casing of the pump, the energy stored up in this rapidly moving water is almost entirely changed to pressure. The speed of the chestnut rests upon two factors—the length of the string and the number of revolutions made within a specified period of time. The speed, and hence the resulting pressure, imparted to water by a centrifugal pump also rests upon the same two factors—the diameter of the impeller and the number of revolutions per minute which the impeller makes.

There are, of course, practical limits to both the speed and the diameter so that it is not always possible to secure the full desired pressure with one pump. If not, the water is passed through two or more pumps in series, and each pump raises the pressure part of the total desired amount. Sometimes these two or more pumps are built in one pump case, in which instance each pump is called a "stage" Since electrically driven centrifugal pumps operate at fixed speeds, there is always one head under which a pump will operate most efficiently. Right here it will not hurt to repeat that any material deviation from this condition will result in decreased efficiency.

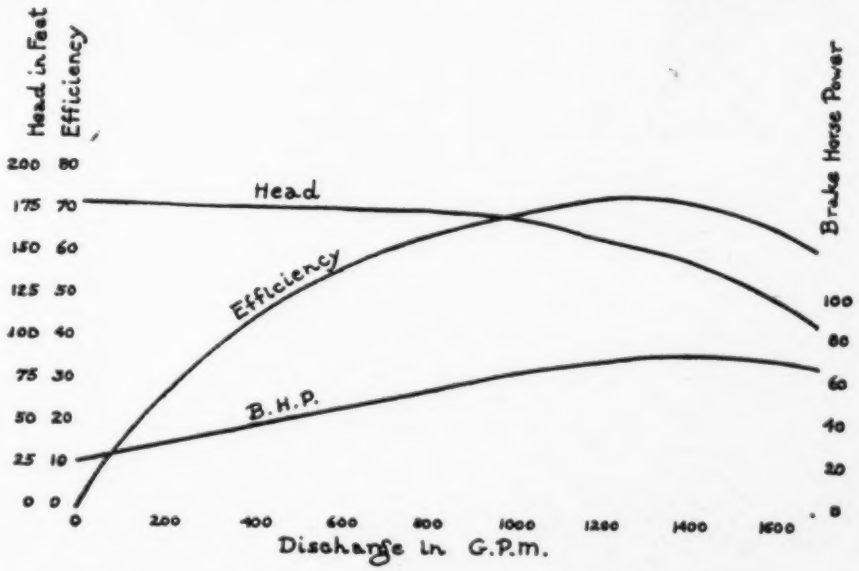
Pump Performance Curves

At this point I want to introduce a typical centrifugal pump curve which we will use for illustration during this discussion. Similar curves are available from the manufacturer for all medium sized and large pumps. On small pumps it is not customary to furnish such performance curves.

It will be noted from an inspection of the specimen curve that the greatest efficiency for this particular pump (about 75%) is secured when the head is about 155 ft. and the discharge rate is about 1,300 G.P.M. You will also note that as the head is materially increased or decreased from the optimum head there is a large change in the pumping rate and a considerable drop in efficiency. A great deal has been done in design effort to widen out the "peak" of the efficiency curve into a "plateau" so as to give high efficiencies for centrifugal pumps under a wider range of operating conditions. Considerable progress has been made in this direction.

Friction Head—Its Importance

Let us see what happens when we forget to include pipe friction loss when figuring the total head against which the pump must operate. If we have figured on the pump whose curve we have, and if we are pumping through two miles of 16" main, the friction loss will add about 18 ft. to the pumping head—making it 173 ft. At this head (see curves) the pumping rate will drop to 1,000 G.P.M. and the efficiency to 70%. Furthermore, the pump is operating on a very critical part of the curve where a slight increase in pumping head—caused by tuberculation in the main or by any other reason—would incur a precipitate drop in both the efficiency and the pumping rate. It also illustrates what can happen to a pump, after installation, when the pumping head has been increased above the head for which it was designed. As



An Example of Typical Performance Curves for Centrifugal Pumps. Various designs show individual characteristics in respect to the curves produced.

* Excerpts from a paper presented before the Penna. Water Operators Association and an earlier article by Mr. Beckwith in previous Reference & Data Issues of this magazine

it is the nature of unlined iron and steel mains to tuberculate, resulting in a constantly rising friction loss, this is an important consideration.

Let us illustrate this in another way.

Selecting the Right Pump

Suppose that we are in the market for a 1,000 G.P.M. pump operating against a total head of 173 ft., and a pump whose curve we have been using has been submitted for consideration. I would not consider this pump a good "buy" to operate under these conditions. In the first place it will be noted that the efficiency of 70% is much below the maximum efficiency of 75%. But even more important, perhaps, is the fact that the pump at 173 ft. head is operating under "critical head" conditions. An increase of only about 8 ft. (less than 5%) in the pumping head would bring the head to the maximum which the pump can create—in other words to the "cut off" point. This means that an increase in the head of only 8 ft. (about 3½ pounds) would decrease the pumping rate from 1,000 G.P.M. to zero G.P.M. Moreover an increase of only 3 ft. in head would cause a drop of 200 G.P.M. in the pumping rate. On the other hand, when we are working in the most efficient range of the pump a change of 3 ft. in the head would only cause a variation of 30 to 40 G.P.M. in the pumping rate; and, the efficiency is practically unaffected.

It follows, therefore, that one should buy a pump within the range where the efficiency curve is as *flat* as possible and the head curve is as *steep* as possible. In this connection a word of warning may not be amiss. By making the vertical scale of the curve less than is customary, a much flatter *appearing* efficiency curve can be secured. So in comparing the performance curves of pumps be sure that they are plotted on comparable scales. I have known curves with reduced vertical scales to be submitted where I felt sure that the scale was deliberately reduced for the purpose of deception.

Mistaken Economy

Only too often in the revamping of a plant, efforts are made to re-use as much of the old equipment as possible. It may be assumed that if the old pump will handle 1,300 G.P.M. against 155 ft. of head it should have less trouble pumping the same amount from the river to the settling basin against a head of only forty or fifty feet. This is so. In fact, if we will look at the curve we will find it will pump much more than 1,300 G.P.M. at the lower head. The curve does not go out that far, but it goes far enough to show what would happen—not only to the pumping rate but to the efficiency as well. The pumping *rate goes up* but the *efficiency goes down*—yes, way down. Reducing the head has a tendency to cause a pump to run away much as an automobile would run away down hill when the going becomes easier if the throttle were not closed to compensate for the decreased demand for power. This running away of the pump sometimes overloads the motor so that it runs hot. To prevent this, operators raise the head artificially by partly closing a valve on the outlet side of the pump. This decreases the load on the motor and brings the pumping rate back to normal. But it burns up a great deal of power needlessly as the closed valve destroys part of the head generated by the pump and only part of the work actually performed is effective. I have known of installations, such as this, where the installation of a new pump saved more than enough power in one year to pay the entire cost of the new pump and motor and also completely depreciate the old unit replaced.

But it is not always necessary to buy a new pump just because the head has been reduced. If we will get back to that chestnut on the string we will find that we can reduce the speed of the chestnut by reducing the length of the string, at the same time keeping the number of revolutions constant. In the same manner, we can cut down the pressure generated by a constant speed centrifugal pump by reducing the diameter of the runner. If the reduction in head is moderate, the manufacturer can advise you how much will have to be machined off the outside of the present impeller so that it will pump efficiently, or at a slight expense he will furnish a new impeller for the changed conditions. Or he may cut down your old impeller.

It is sometimes possible to secure a larger impeller to efficiently handle increased heads, but in this case the motor is likely to be overloaded unless the original specification anticipated such change as loads increased.

Another way to increase the speed of that chestnut would be to keep the length of the string constant and to increase the number of revolutions. It follows that if we increase the revolutions of any centrifugal pump we will increase the head which that pump will generate. This explains why a certain pump tested last fall gave a wire to water efficiency of only 40%. This pump was designed for use with a gasoline motor and to operate under the then existing head conditions at a speed of 1400 R.P.M. Eventually electric power became available and the pump was connected to an electric motor and the speed increased to 1,800 R.P.M. This, of course, increased the head generated by the pump itself, and the efficiency was consequently very low.

A somewhat similar condition was found several years ago when a 5 M.G.D. installation designed to work against a head of 100 pounds was found to have been connected in series to a 5 M.G.D. pump designed to pump against 50 pounds pressure. This gave an installation with a design head of 150 pounds, but the actual head was still only about 100 pounds. The *output* was thereby *increased* to approximately 6 M.G.D. but the *efficiency decreased* to the point where it was only slightly above 40%. New and properly designed equipment brought the wire-to-water efficiency up to about 75%.

It can be readily seen from the above considerations that the chances of buying a suitable pump from the "junk man" are just about nil. It might be "as good as new" for the conditions for which it was designed and yet be absolutely worthless under any other conditions. In fact, it would probably be a most expensive liability. Yet pumps have been bought from the equivalent of "junk men", but most frequently have been "salvaged" by the original purchaser for other duty than originally purchased for.

So far, we have been discussing equipment which has been working under conditions which made it impossible to give a creditable showing. A mere inspection of the conditions and a knowledge of the design limitations would make it evident that satisfactory performance under these conditions could not be secured. However, there are occasions where, after installation, things happen to properly selected pumps which will cut the efficiency of the equipment. There was, for instance, the time

Table I—Gallons of Water Delivered per Kilowatt Hour Against Various Heads on Theoretical Assumption That Pump and Motor Are 100 Per Cent Efficient

H = head in feet. G = gallons per kilowatt hour

H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
1	318,200	51	6,240	101	3,151	151	2,106	201	1,583	251	1,268	301	1,058	351	907	401	794	451	706
2	159,100	52	6,120	102	3,120	152	2,094	202	1,575	252	1,263	302	1,054	352	904	402	792	452	704
3	106,100	53	6,005	103	3,090	153	2,080	203	1,567	253	1,258	303	1,051	353	902	403	790	453	703
4	79,560	54	5,894	104	3,060	154	2,067	204	1,560	254	1,253	304	1,047	354	899	404	788	454	701
5	63,650	55	5,786	105	3,031	155	2,053	205	1,552	255	1,248	305	1,044	355	897	405	786	455	700
6	53,040	56	5,683	106	3,002	156	2,040	206	1,545	256	1,243	306	1,040	356	894	406	784	456	698
7	45,460	57	5,583	107	2,974	157	2,027	207	1,537	257	1,239	307	1,037	357	892	407	782	457	697
8	39,780	58	5,487	108	2,947	158	2,014	208	1,530	258	1,234	308	1,033	358	889	408	780	458	696
9	35,360	59	5,394	109	2,920	159	2,002	209	1,523	259	1,229	309	1,030	359	887	409	778	459	694
10	31,830	60	5,304	110	2,893	160	1,989	210	1,516	260	1,224	310	1,027	360	884	410	776	460	692
11	28,930	61	5,217	111	2,867	161	1,977	211	1,508	261	1,220	311	1,024	361	882	411	775	461	691
12	26,520	62	5,133	112	2,842	162	1,965	212	1,501	262	1,215	312	1,020	362	879	412	773	462	690
13	24,480	63	5,051	113	2,816	163	1,952	213	1,494	263	1,211	313	1,017	363	877	413	771	463	687
14	23,730	64	4,972	114	2,794	164	1,940	214	1,487	264	1,206	314	1,014	364	875	414	769	464	686
15	21,220	65	4,896	115	2,766	165	1,929	215	1,480	265	1,202	315	1,011	365	873	415	767	465	685
16	19,890	66	4,822	116	2,744	166	1,917	216	1,474	266	1,197	316	1,007	366	870	416	765	466	683
17	18,720	67	4,750	117	2,720	167	1,906	217	1,467	267	1,193	317	1,004	367	868	417	763	467	682
18	17,690	68	4,680	118	2,697	168	1,894	218	1,460	268	1,188	318	1,001	368	865	418	761	468	680
19	16,750	69	4,611	119	2,674	169	1,883	219	1,453	269	1,184	319	998	369	863	419	760	469	679
20	15,910	70	4,547	120	2,652	170	1,872	220	1,447	270	1,179	320	995	370	860	420	758	470	677
21	15,150	71	4,482	121	2,630	171	1,861	221	1,440	271	1,175	321	992	371	858	421	756	471	676
22	14,470	72	4,420	122	2,609	172	1,851	222	1,434	272	1,170	322	989	372	856	422	754	472	675
23	13,830	73	4,360	123	2,588	173	1,840	223	1,427	273	1,168	323	986	373	854	423	753	473	674
24	13,260	74	4,301	124	2,567	174	1,829	224	1,421	274	1,162	324	982	374	851	424	751	474	672
25	12,730	75	4,243	125	2,546	175	1,819	225	1,414	275	1,158	325	979	375	849	425	749	475	671
26	12,240	76	4,188	126	2,526	176	1,809	226	1,408	276	1,154	326	976	376	847	426	747	476	669
27	11,790	77	4,133	127	2,506	177	1,798	227	1,402	277	1,150	327	973	377	845	427	746	477	668
28	11,370	78	4,080	128	2,486	178	1,788	228	1,396	278	1,146	328	970	378	842	428	744	478	666
29	10,970	79	4,028	129	2,467	179	1,778	229	1,390	279	1,142	329	968	379	840	429	742	479	665
30	10,610	80	3,978	130	2,448	180	1,768	230	1,384	280	1,137	330	965	380	838	430	740	480	663
31	10,270	81	3,929	131	2,429	181	1,758	231	1,378	281	1,133	331	962	381	836	431	739	481	662
32	9,945	82	3,882	132	2,411	182	1,749	232	1,372	282	1,129	332	959	382	833	432	737	482	660
33	9,644	83	3,834	133	2,393	183	1,739	233	1,366	283	1,125	333	956	383	831	433	736	483	659
34	9,360	84	3,789	134	2,375	184	1,729	234	1,360	284	1,121	334	953	384	829	434	734	484	658
35	9,093	85	3,744	135	2,358	185	1,720	235	1,354	285	1,117	335	950	385	827	435	732	485	657
36	8,840	86	3,701	136	2,340	186	1,711	236	1,349	286	1,113	336	947	386	825	436	730	486	655
37	8,601	87	3,658	137	2,323	187	1,702	237	1,343	287	1,109	337	945	387	823	437	729	487	654
38	8,375	88	3,617	138	2,306	188	1,693	238	1,337	288	1,105	338	942	388	820	438	727	488	653
39	8,160	89	3,576	139	2,292	189	1,684	239	1,332	289	1,102	339	939	389	818	439	725	489	651
40	7,956	90	3,536	140	2,274	190	1,675	240	1,326	290	1,098	340	936	390	816	440	723	490	650
41	7,762	91	3,497	141	2,257	191	1,666	241	1,320	291	1,094	341	934	391	814	441	722	491	649
42	7,577	92	3,458	142	2,241	192	1,658	242	1,315	292	1,090	342	931	392	812	442	720	492	647
43	7,401	93	3,422	143	2,225	193	1,649	243	1,310	293	1,087	343	929	393	810	443	719	493	646
44	7,233	94	3,386	144	2,210	194	1,640	244	1,304	294	1,083	344	926	394	807	444	717	494	645
45	7,072	95	3,350	145	2,195	195	1,632	245	1,299	295	1,079	345	923	395	805	445	716	495	644
46	6,916	96	3,315	146	2,180	196	1,624	246	1,294	296	1,075	346	920	396	804	446	714	496	642
47	6,771	97	3,281	147	2,165	197	1,615	247	1,288	297	1,072	347	918	397	802	447	713	497	641
48	6,630	98	3,248	148	2,150	198	1,608	248	1,284	298	1,068	348	915	398	800	448	710	498	640
49	6,493	99	3,215	149	2,136	199	1,600	249	1,278	299	1,065	349	913	399	798	449	709	499	639
50	6,366	100	3,183	150	2,122	200	1,592	250	1,273	300	1,061	350	910	400	796	450	707	500	638

when we found a water snake wrapped around the shaft with the result that the inlet ports were partially cut off and the suction lift increased way beyond the 15 feet maximum for best performance. In another and similar situation blocks of wood were found jammed in the ports. Then there was the time that low efficiency was caused by the blowing of the gasket of a multiple stage pump and the water was short circuiting back from a higher stage to a lower stage. One of our engineers once reported that an efficiency of 20% was caused by the impeller slipping on the shaft.

Two interesting conditions have been found by the author which have no reference to the actual efficiency of the pumps but which were determined as th result of making efficiency tests. In one instance, where the meter through which power was purchased was used to measure the power input, it was found that an apparent low efficiency was caused by this meter being set 20% high. In another instance, a pump was discharging into a closed distribution system. On the basis of the water *actually discharged* into the system (24-hour period) the pump had an efficiency of only 8%. Had a standpipe or reservoir been floating on this system, the same amount of water could have been pumped with about one-eighth the amount of power which was actually used.

So much for the reasons why efficiency tests should be made at intervals.

A Simple Efficiency Test

The writer has worked out a simple method for making efficiency tests which he has been using with satisfactory results for some years.

At one foot of head and 100% efficiency of *both pump and motor* it is theoretically possible to raise 318,200 gallons of water one foot with one KW.H. To determine this theoretical value for any other head, simply divide 318,200 by the head involved. For instance, the value at 150 ft. would be $\frac{318{,}200}{159} = 2{,}002$ gallons per KW.H. In this connection the accompanying "Table of Theoretical Values for Various Heads" may prove helpful in reducing calculations in pump testing. It was prepared by the writer and has appeared in earlier Reference and Data Numbers of WATER WORKS AND SEWERAGE.

To determine the *wire-to-water efficiency* of an installation it is only necessary to divide the actual pumpage per KWH by the theoretical value for the pumping head, as determined from the table. A rough check can be made by dividing the month's pumpage in gallons by the KWH consumed. This gives the gallons actually pumped per KWH.

Test Procedure

With the pump running, determine the total head in feet (including suction) against which the pump works. Divide 318,200 gallons by this total head (as above) to determine the theoretical 100% pumpage per KWH. (Or take the figure from Table 1.) Next divide the actual gallons per KWH by the theoretical gallons per KWH to secure the wire to water efficiency.

To illustrate:

Assume a monthly pumpage of 32,640,000 gallons and a monthly power consumption of 30,200 KWH. Say the total head noted was 220 ft. Dividing 32,640.000 by 30,200 gives an actual pumpage of 1,081 gallons per KWH. Dividing 318,200 by 220 ft. gives a theoretical value of a possible 1,447 gallons per KWH at 100% efficiency (see table). Then;

$$\frac{1{,}081 \text{ (observed)}}{1{,}477 \text{ (theoretical)}} = 74.7\% \text{ overall}$$

wire to water efficiency.

A more accurate method of making the tests is to measure the power input for an hour, or some other convenient period of time. During this period carefully check the output of the pump with any suitable main line meter. Keep a close record also of the discharge pressure and of the suction. The integrations on most electric meters in pumping stations cannot be read closely enough for short tests. However, the power company will furnish the number of watts consumed for each revolution of the disk, and by counting its revolutions for ten or twenty minutes the rate of power input can be closely ascertained. Or the power company can be asked to measure the power by means of special equipment. Where more than one pump is taking power through the master meter at the same time, the latter method is the only feasible one for testing each unit separately.

Securing Total Head

The total head in feet must first be secured. If the pressure gauge reads in pounds, convert to feet by multiplying the pounds of pressure by 2.31 [feet of water head giving one pound gauge pressure]. The suction will probably be expressed in inches of mercury. Convert this to feet of water head by multiplying by 1.13. Also measure the vertical distance between the center of the pressure gauge and the point of suction measurement. The total head then becomes the sum of the following:

Discharge pressure, in feet	xxx
Suction, in feet	xx
Vertical distance pressure gauge is above point of suction measurement, feet	x
Total Head in feet	xxx

Velocity head has been ignored, as it is a small factor for the relatively high heads which usually exist in water works operation.

If water is delivered to the pump under pressure, then the pump will be working against a head equal to the difference between the discharge pressure and the inlet pressure.

From the data secured during the test, determine the gallons delivered per kilowatt hour. As before, divide this by the theoretical value for the head against which the pump was operating. This gives the overall wire-to-water efficiency of the installation.

As an example, let us assume an installation where we secured the following test data:

Power input to motor	90.0 K.W.
Rate of discharge	51,840 gals. per hr.
Delivery per KWH	572 gals.
Pressure	146 lbs. = 337 ft.
Suction	15 ins. = 17 ft.
Difference in gauge elevation	1 ft. = 1 ft.
Total head	355 ft.

Theoretical discharge at 335 ft. head (see table) is $\left(\frac{318{,}200}{355}\right) = 897$ gals.

and

Overall efficiency (wire-to-water) is $\left(\frac{572}{897}\right) = 64\%$

If a suction gauge is not available, an approximation may be secured by measuring the vertical distance from the level of water in the clear well to the center of the pressure gauge, adding to this measured distance about two feet for loss in bends, etc.

What the Tests Reveal

Having shown the desirability of frequent tests and having presented a simple method for making them, it may now be interesting to discuss what these tests may be expected to show. In the first place, there have been great increases in the attainable efficiencies of centrifugal pumps within the past few years. Those of modern design may be expected to give up to the following overall (wire to water) efficiencies.

Capacity G.P.M.	Efficiencies Percent
200	58
400	63
600	68
800	71
1000	73
1500	75
3000	80
5000	82
Over 5000	85

It will be noted that the larger the pump the higher the efficiencies.

There will be variations from these figures depending upon the head and other conditions. Such are submitted only for the purpose of giving something with which to compare the efficiencies of existing installations. This is important, because it will often be found that older equipment may have retained its original efficiency and yet be so inefficient in comparison with modern equipment, now available, that it is decidedly not economical to keep it in operation. It will be worth while to check the present efficiency of every centrifugal pump now more than ten years old, to determine how great a reduction in power consumption can be secured by replacement with more efficient modern pumps.

If an old 1,000 gpm pump, operating at an efficiency of 57%. is replaced with a new pump giving an overall efficiency of 73% You may be surprised.

ine same amount of water may be pumped with 22% less power. This means that both the demand rate and the power consumption through each step of the existing rate schedule would be decreased 22%. Such a reduction might prove enough to pay for the new installation in about one year's time. In order to get the gallons per KWH to be expected at any head, for any efficiency, it is only necessary ot determine theoretical gallons per KWH for that head and then to multiply this theoretical value by the expected efficiency. If the total pumpage in gallons is then divided by this expected pumpage per KWH the power consumption to be anticipated from the new installation will be secured. Similarly it is possible to determine the anticipated demand rate, which is often as important (if not more so) than is the total KWH consumption in determining the power bill to be expected from a new installation.

A Worthy Example

In the March, 1939, issue of WATER WORKS AND SEWERAGE an article by Messrs. Marshall and Rawlins of Charlotte, N. C., revealed graphically how the power costs were drastically cut at the local pumping station by replacing old equipment with new. These power costs, which had been running about $16.00 per million gallons were cut to about $7.50 per million gallons. This cut was the result of two definite and distinct improvements. In the first place the pumping main was paralleled with a new line. This resulted in reducing the former friction loss materially. This single betterment cut the power cost from $16.00 to $12.00 per million. Following this, the not very old (but less efficient) pumping units were replaced with modern efficient equipment. This investment, which might appear to the average municipal councilman a questionable expenditure, further reduced the pumping cost to $7.50 per million, representing a very notable day in and day out saving.

Measuring Output of Water

Table I has another use. Many plants, especially smaller ones, have no master meters. With the old displacement type pump it was possible to secure the approximate amount of water pumped by installing a pump stroke counter and multiplying the number of strokes by the discharge in gallons per stroke. If the pump were permitted to get into a state of disrepair, this measurement was apt to be in error, but if the pump were kept in good condition it was reasonably accurate. The method about to be outlined for obtaining the output of water from electrically operated centrifugal pumps has possibly a degree of accuracy comparable to the pump counter method.

From the efficiency curve furnished with the pump, determine the pump efficiency for the head under which the pump operates. The curve will show the pump efficiency only. The combined pump and motor efficiency, the so-called wire to water efficiency, will be about 90 per cent of the efficiency shown for the pump alone. From Table 1 secure the theoretical gallons per kilowatt hour for the head under which the pump is operated. Multiply this by the overall wire to water efficiency just secured. This gives the number of gallons per kilowatt hour the pump should deliver. Multiply this by the total number of kilowatt hours used over any given period of time and the result should be the number of gallons pumped over the sam period. To illustrate:

Assume a pump with an efficiency of 65 per cent operating at a total head of 200 ft. Then 90 per cent of 65 would give an overall wire to water efficiency of 58.5 per cent. If the installation were 100 per cent efficient, Table 1 indicates the discharge would be 1,592 gallons per kilowatt hour. With an overall efficiency of 58.5 per cent the discharge would be 1,592 × 58.5 per cent, or 931 gal. If the power consumption for the month be 20,000 kilowatt hours, then the total pumpage becomes 20,000 × 931 or 18,260,000 gal. for the month.

While this method of computing pumpage will not, as a rule, give results as satisfactory as those secured from a master meter, it does give a close approximation in instances where a master meter is not available.

In outlining the tests in this paper it has not been intended to supplant the more detailed methods used by professional engineers, but to make available to the average water works operator a method of checking which will give reasonably accurate results.

TERMINOLOGY IN PUMPING*

Static Head

Static Head is the vertical distance in feet between the free level of the source of supply and the point of free discharge, or to the level of the free surface of the discharge water.

Total Dynamic Head

Total Dynamic Head, as determined on test, where Suction Lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to discharge nozzle of pump, plus vertical distance between point of attachment of mercury column and center of gauge, plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Total Dynamic Head, as determined on test, where Suction Head exists, is the reading of a gauge attached to the discharge nozzle of pump, minus the reading of gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending on whether suction gauge is below or above discharge gauge), plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where instruments are attached.

Total Dynamic Discharge Head. is the Total Dynamic Head minus Dynamic Suction Lift, or plus Dynamic Suction Head.

Total Dynamic Head is the vertical distance between source of supply and point of discharge when pumping the required capacity, plus Velocity Head, plus friction and entrance losses.

Suction Lift

Suction Lift exists where the source of supply is below the center of pump.

Static Suction Lift is the vertical distance from the free level of source of supply to center of pump.

Dynamic Suction Lift is the vertical distance from the source of supply, when pumping required capacity, to center of pump, plus Velocity Head, plus entrance, and friction losses; but not including internal pump losses.

Dynamic Suction Lift, as determined on test, is the reading of a mercury column connected to suction nozzle of pump plus vertical distance between point of attachment of mercury column to center of pump, plus head of water resting on mercury column, if any.

Suction Head

Suction Head (sometimes called Head on Suction), exists when source of supply is above center of pump.

Static Suction Head is the vertical distance from the free level of the source of supply to center of pump.

Dynamic Suction Head is the vertical distance from the source of supply, when pumping at required capacity, to center of pump, minus Velocity Head, minus entrance, and friction losses; but not minus internal pump losses.

Dynamic Suction Head, as determined on test, is the reading of a gauge connected to suction nozzle of pump. minus vertical distance from center of gauge to center of line pump. Suction Head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to Suction Lift will prevail.

*From "Hydraulic Data," an Ingersoll-Rand Hand-Book.

CONSERVATION OF CENTRIFUGAL PUMPS

B. L. CODY
Centrifugal Pump Department
Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

PUMPING equipment, like all other types of machinery, must be conserved so as to release more men, material, and machine tools for the vital purpose of producing for victory. To achieve this end, no machine should be allowed to use up more than its normal ration of energy.

The better designs of pumping equipment have been built to operate continuously year after year with only sufficient lost time to follow a definite maintenance timetable, but that timetable is all important. Every pumping unit in a given plant should be classified as to its maintenance requirements and grouped in a maintenance index with all others requiring the same pattern for servicing.

Although operating conditions in each plant vary greatly, making it impossible to set up one maintenance timetable for all pumping units, four major factors influencing a pump maintenance system will help in classifying units. They are:

(1) Number of operating hours per month.
(2) Injurious chemicals, dust, and moisture in the air which collect on pump parts.
(3) Liquids being handled by the pump.
(4) Amount of inspection the unit received from engineers.

A pump operating 720 hours a month, with dust from a nearby rock crusher settling over it, handling a liquid which will in time consume the pump material, and receiving little or no attention from engineers, will require the attention of the maintenance crew constantly.

Let us assume, however, that there is a spare pump for relief work and that both pumps are protected from the dust. They are built of a material suitable for handling the liquid, and the shift engineers inspect the pump unit regularly each shift. Such favorable conditions should be obtained for pumping equipment wherever possible, for then and only then are the advantages of preventive maintenance possible. The maintenance crew can then adopt a maintenance schedule from the following general timetable:

Every Year

(1) Dismantle pump completely. Refer to Fig. 2 for section of typical pump with parts listed.
(2) Inspect every part thoroughly for wear.

(a) Shaft sleeves should be replaced if grooved in such a manner that they will damage stuffing box packing or will wear through before another yearly inspection.

(b) Wearing rings should have a diametrical clearance of about 0.006 to 0.008 inch on cold water service and about 0.010 to 0.012 inch on hot water service when new. When ring clearance becomes 0.020 to 0.030 inch on the diameter, it is more economical to replace the rings than to pay for the power lost in leakage through them.

(c) Bearings: Ball bearings should be cleaned thoroughly with kerosene and inspected for defects causing rough operation. Ball bearings should always be removed from a shaft with a puller on the inner race. When dismantling or assembling a ball bearing on a shaft, force should never be exerted through the balls from one race to another. Sleeve bearings should be cleaned with kerosene and inspected for pitting, wiped areas, and high points. If pitting is occurring, the oil used for lubrication should be investigated. Stray electrical currents will also cause pitting. Wiped areas show points in the bearing where lubrication was insufficient to take care of the bearing pressure at that point. If the bearing pressure at any given point becomes so great that an oil film cannot be maintained between the shaft and bearing babbitt, wiping occurs. Any wiped areas, if not more than 15 per cent of the total bearing surface, can be scraped and the bearing put back in operation. A well-fitted sleeve bearing should have a high polish on at least 80 per cent of the total bearing surface after a year's operation. In the event of the necessity of replacing a sleeve bearing where no factory-built spares are available, the following points should be considered:

The best grade of babbitt should be used.

A pot casting should be turned out on an accurate lathe, for inserting the bearing shell to ensure perfect alignment when boring out the babbitt.

The diametrical clearance in a sleeve bearing should be about 0.001 per inch of diameter plus 0.002 for most pump bearings.

Oil grooving and relieving of the sides of the new bearing should be the same as that replaced.

(d) Stuffing box packing should be inspected and any rings which are not pliable or rings which have lost their shape and structure should be replaced.

(e) Casting and runner should be cleaned and inspected for wear, deposits, or pitting. If any of these conditions are encountered, attempts should be made to correct the cause so as to obtain more efficient and longer service from the unit.

(f) Inspection should be made of all auxiliary equipment and fittings such as check valves, foot valves, outside seals, priming equipment, and gages.

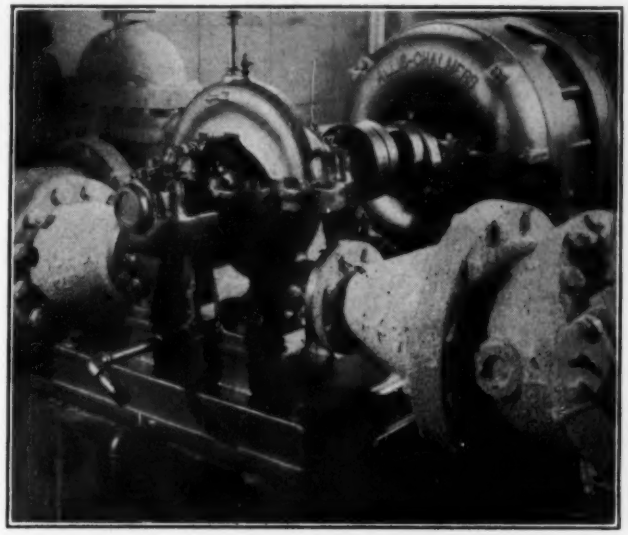


Fig. 1.—Single-stage double-suction pump with eccentric reducer on suction side and concentric decreaser on discharge side. (Part of overall maintenance program requires cleaning to assure maximum operating efficiency.)

Every Six Months

Inspect and replace stuffing box packing and shaft sleeves, if necessary; check alignment of pump and driver. Determine if piping has shifted in any manner so as to throw a strain on the pump casing. Disconnect suction and discharge piping to see if it springs in any direction, thus indicating a strain on the pump. Check all piping supports to see that they are effectively supporting the load.

Listen to each bearing with an ear to the rod. If any are rough, investigate their condition.

Every Three Months

Drain lubricant, flushing out oil or grease wells and bearings with kerosene. Check oil rings to see that they turn freely with the shaft and are not defective. Measure clearance in sleeve bearings to see that the wear has not increased to a point where the rotating element rubs in the ring fits.

Every Month

Check bearing temperature with thermometer, not by hand. If antifriction bearings are running hot, they probably have too much lubricant. If sleeve bearings are running too hot (over 150° F.) they probably need a different grade of oil or more lubrication. If change in lubrication does not correct condition, disassemble and inspect bearings. Check to see that there are no high spots and that the oil grooves are located so as to ensure even lubrication. When hot bearings are encountered, the alignment of the drive should be checked at operating temperature.

Dismantling

When a pump is dismantled, the upper half casing should be raised just far enough to insert a long-bladed knife to strip the

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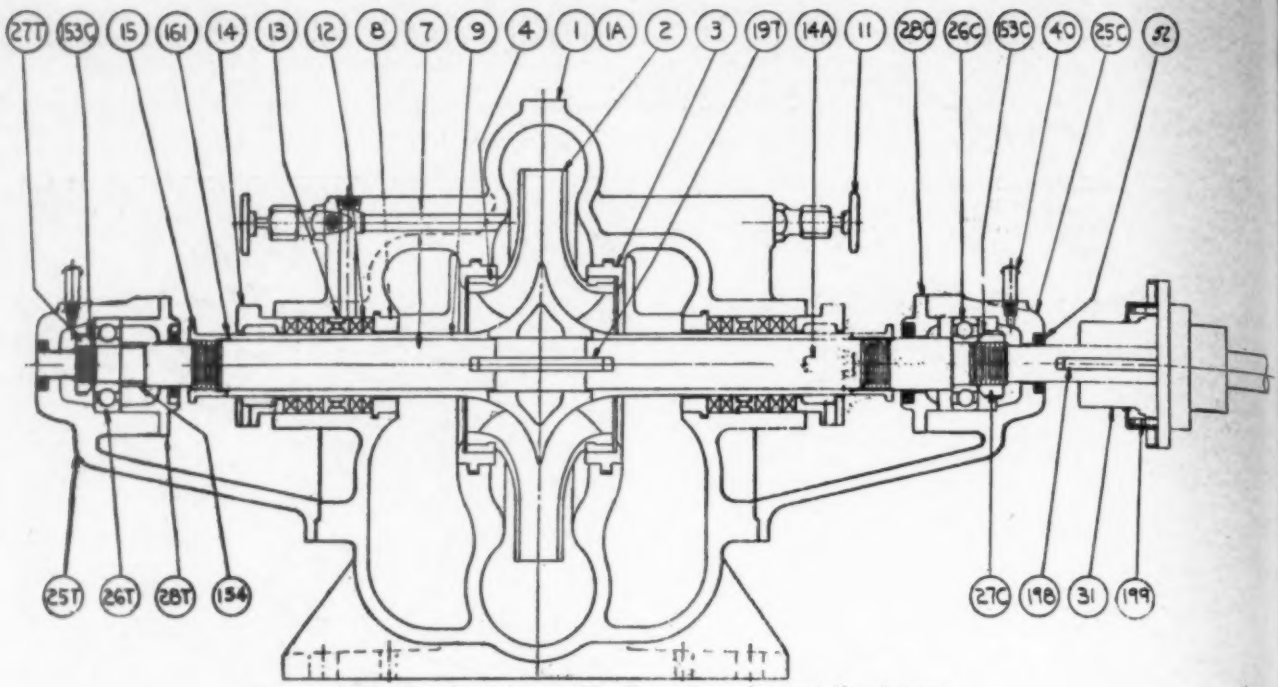

Fig. 2.—General assembly, Type S marine centrifugal pump.

Part No.	NAME OF PART	No. a
1	Casing	1
1A	Casing gasket	1
2	Runner	1
3	Casing wearing ring	2
4	Runner wearing ring	2
7	Shaft	1
8	Stuffing box bushing	2
9	Shaft sleeve	2
11	Waterseal valve	2
12	Packing ½-inch sq	13 ft.
13	Water-seal ring (split)	2
14	Gland (split)	2
14A	Gland bolt and nut	4
15	Shaft sleeve nut	2
26C	Ball bearing	1
26T	Ball bearing	1
27C	Retaining nut	1
27T	Retaining nut	1
31	Complete coupling	1
40	Grease fitting	2
25C	Ball brg. housing	1
25T	Ball brg. housing	1
28C	Ball brg. end cover	1
28T	Ball brg. end cover	1
134	Brg. spacer sleeve	1
153C	Lock washer	1
52	Grease retainer	1
161	Cord packing	Nec.
197	Runner key	1
198	Coupling key	1
199	Coupling spring	1

a Per pump.

gasket off one of the casing halves. Unless this is done the gasket will probably be damaged. If replacement is necessary, the new gasket should be within 0.001 inch of the thickness of the damaged gasket. The new gasket should not be cut with a ball peen hammer but with a knife, scissors, or file. Care should be taken to make it fit exactly around the casing wearing rings and bushings and to see that these joints are not damaged when the gasket is cut.

When a new gasket is installed, it should be held in place on the lower half casing by means of a heavy grease and not with a compound which will set up, become hard, and form an uneven surface. The gasket should cover the entire joint and not leave a groove behind wearing rings and bushings through which water can pass. Any leakage passing through these machined fits will eventually cut out the metal at the joint, and welding of the casing will be required.

Gasket material should extend into the stuffing box at the joint between the upper and lower casing. If the gasket does not extend to the inside of the stuffing box, a groove is left along the inside at the joint which the packing cannot seal, no matter what pressure is exerted on the packing.

The packing and care of a stuffing box are the most important items of a pump considering maintenance time and cost. Stuffing-box packing should never be put in a pump before the two casing halves are bolted together. Some maintenance men feel they are saving time by doing this, but in most cases initial time saved shows up as loss when the extra time required every day for adjusting packing and the sleeve wear encountered are taken into consideration.

To pack a stuffing box properly, every ring of packing should be greased and forced to the bottom of the stuffing box. Metal rings the size of the water-seal rings should be used to compress each ring individually. After the last ring of packing has been compressed, the gland plate nuts should be tightened to finger tightness. The pump should be primed and operated for a very short interval until the packing has had a chance to form a very smooth and solid surface on the packing next to the shaft sleeve. It should not be operated for any length of time, however, with the packing compressed tightly in the stuffing box because of the danger of burning the packing or scoring the sleeves. The pump should be operated for about one-minute intervals with sufficient time between operating periods to allow the packing to cool. After the pump has relieved itself in the stuffing boxes to the point where it turns over freely, it should be put in continuous operation. The gland nuts should be kept finger tight so as to have a little leakage from the gland.

Increasing Pump Capacity

With machinery often operated at full capacity, a pump may be required to deliver extra capacity in order to keep all other equipment in the system operating at full load. This extra capacity can be obtained by chipping back the under side of the outlet vane tip so that it tapers to a thin section at the tip instead of being blunt as illustrated in Fig. 3.

More capacity can be obtained if the pump is belt-driven by increasing the diameter of the drive pulley after proper consideration of the loading of the pump shaft and drive.

If none of the foregoing are feasible, check over the discharge

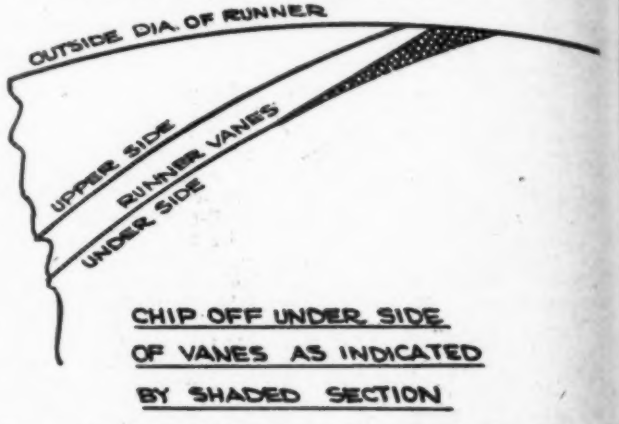

Fig. 3.—Means of chipping under side of outlet vanes to obtain increased capacity.

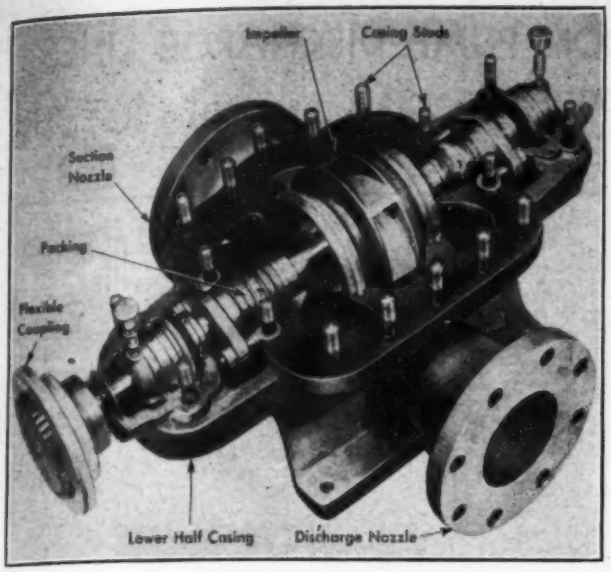

Fig. 4.—Horizontal pump with upper half casing removed.

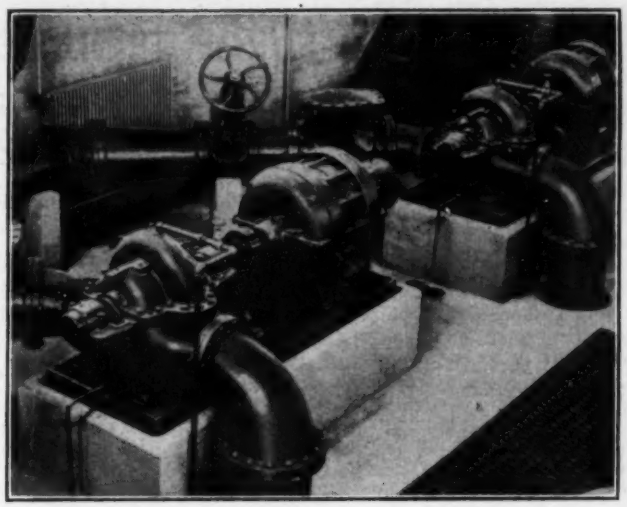

Fig. 6.—Centrifugal pump units installed in a water works. (When either pump is out of service it is checked according to a carefully outlined schedule of pump care.)

piping to see if it has been added on "ranch house" style as the plant expanded. If the length of piping and number of elbows can be reduced, the friction head for the pump to overcome is also reduced and greater capacity can be obtained. About 90 per cent of pumping trouble and lack of capacity can be traced to the piping connecting the pump with its source of supply.

The greatest errors in suction piping are found in cases where a reciprocating pump has been replaced with a centrifugal type pump. In such cases the operators do not always realize that suction to a centrifugal pump is all-important, whereas with a reciprocating pump it is of very little importance.

The suction line to a centrifugal pump should be at least one size larger than the pump suction nozzle. It should be connected to the pump nozzle by an eccentric and not by a concentric reducer. A concentric reducer will allow an air pocket to be formed ahead of the pump nozzle.

Any air pocket in the suction of a centrifugal pump is liable, if drawn into the pump, to cause it to run dry, lose its prime, and "seize." Seizing usually occurs in the wearing ring fits, interstage bushings, or stuffing box bushings owing to metals operating in contact with each other and having no liquid to lubricate them. Consequently, from a maintenance and operational viewpoint, every high point or air pocket in a suction line should be removed.

The capacity of a pump will be reduced considerably by an air pocket floating in the suction pipe like the bubble in a carpenter's level. An air pocket acting in the above manner restricts the flow and increases the friction loss in the suction line.

Operators will often try to force power plant systems to assume overloads they were not designed to handle. When this is done by raising the suction temperature of pumps handling hot water, as in the case of boiler feed pumps, trouble on account of flashing very often results. Flashing in a pump has the same effect as a pump getting "air bound." The pump will in some cases lose its prime and "seize," with lost time for repair resulting.

By locating a pump unit in a favorable position and considering the problem of maintenance from the very beginning, more effective conservation will undoubtedly result and longer life will definitely be obtained.

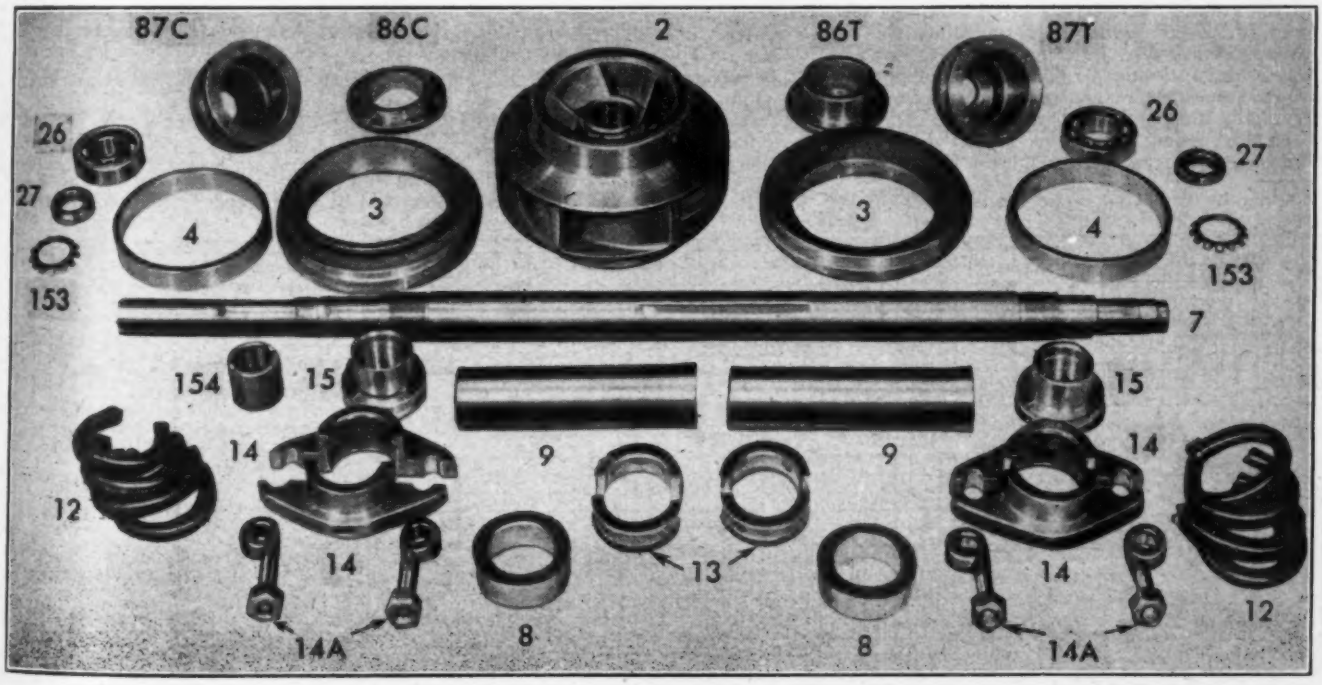

Fig. 5.—Parts of typical horizontal pump with ball bearings.

ELIMINATING SURGE TROUBLES ON PUMP DISCHARGE LINES*

By D. M. RADCLIFFE

Engineer, U. S. Engineers' Office, Washington, D. C.

The purpose of this article is to relate a practical means of preventing dangerous surges and water-hammer in water service pipe lines.

There are several means of preventing surges in pipe lines, the best known of which is the surge tank. In most water supply systems it is not practical to provide surge tanks and therefore some other means must be employed if excessive surging is to be eliminated.

A common cause of dangerous water-hammer or surge in pipe lines of water supply systems is failure of the electric power input to motor driven pumping units. This sudden stop in pumping sets up a series of pressure waves or surges in the discharge pipe line. Much has been published with respect to water-hammer and its effects on pipe lines, therefore this article will discuss briefly a practical means of eliminating surge or water-hammer conditions. The method described is in satisfactory operation on the Washington Aqueduct in the city of Washington, D. C.

The Dalecarlia Pumping Station is equipped with nine synchronous motor driven centrifugal pumping units of 10 and 20 m.g.d. capacities. Three discharge pipe lines extend from the station to service reservoirs. One is a 48-inch pipe line, 12,350 feet in length with 110 feet working head; one a 36-inch line, 8,900 feet in length with 220 feet working head; one a 36-inch line, 15,950 feet in length with 340 feet working head. Three pumps are connected into each of these three lines.

Following accepted practice quick closing check valves had been installed in each of the pump discharge lines. Electric power failures, which occur several times each year, proved the cause of excessive and dangerous surges of water-hammer in the discharge lines. Records of the surges were taken on high-speed pressure charts and it was found that the maximum surge pressures recorded were 175 per cent above normal working pressure on each line.

Rotary Plug Type Check Valves Installed

After the pumping station had been in opertion for approximately three years, it was decided to install check valves which would reduce to a minimum the loss of head through such valves. The new valves installed are of the rotary plug type and hydraulically operated. These are equipped with an adjustable timing feature to provide means of regulating the speed of closing upon pump shut-down or failure of electric power. Timing tests were made on the new valves to determine, if possible, a closing period which would limit pipe line surges to safe values. A number of closing periods, varying from one second to fifteen seconds, were tried. It was not permissible to employ closing periods in excess of fifteen seconds because a reverse flow of water through the pumps would take place and rotate the units backward at high speed. Since the pumps are not designed for reverse rotation this condition was considered unsafe and time of valve closing was limited to a maximum of fifteen seconds. In the series of closing period tests made, it was found that a five second period produced the best results, but the surge was still 100 per cent above normal working pressure. Unless the check valve can be left open until a surge is dissipated and then closed slowly, it is necessary to close the valve before the first supernormal return wave reaches the station or valve. In the case of the Dalecarlia Station, the first

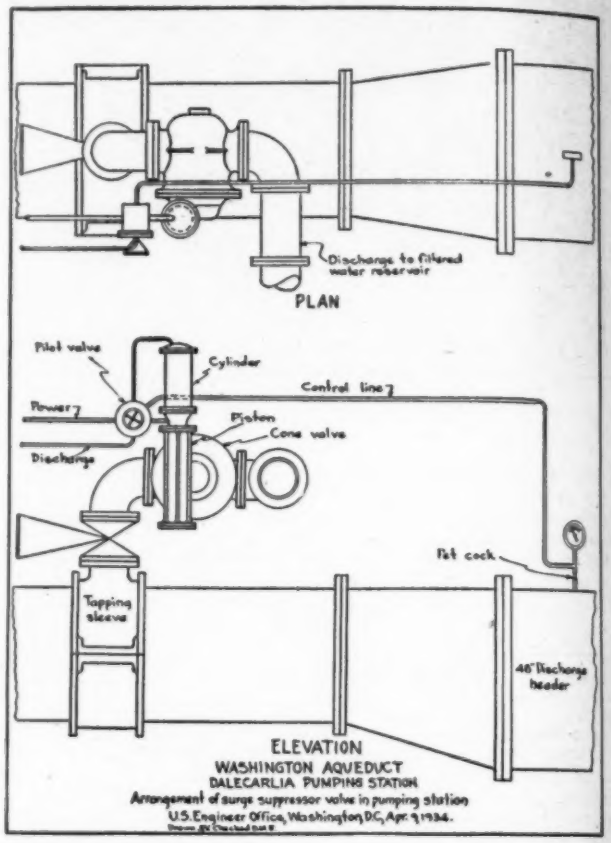

Fig. 2.—Sketch to Show Arrangement of Tapping Sleeve and Surge Relief Valves

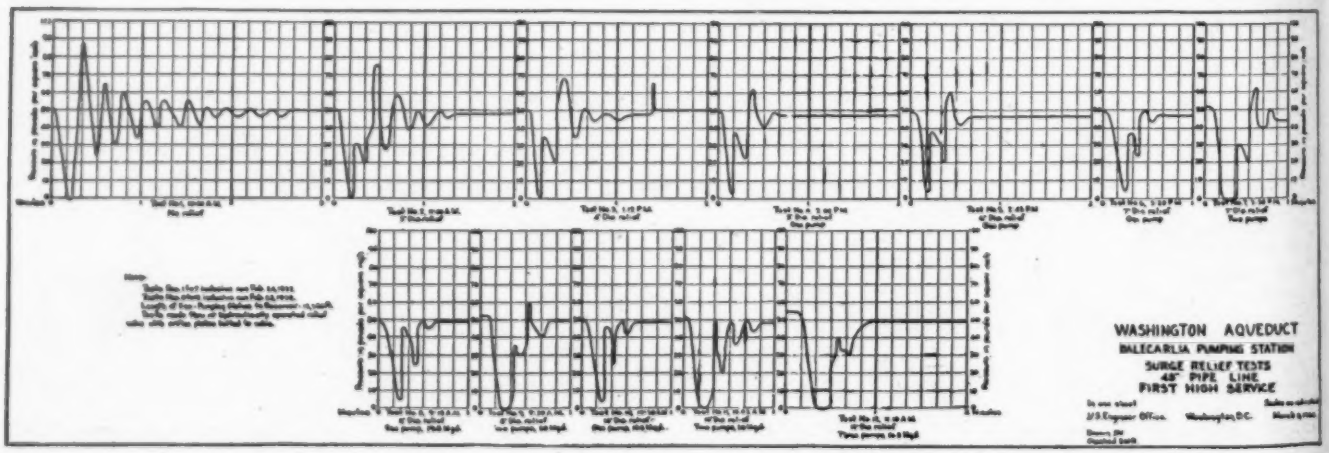

Fig. 1.—Results from Surge Relief Experiments, Employing Various Sizes of Relief Orifice

*From WATER WORKS AND SEWERAGE

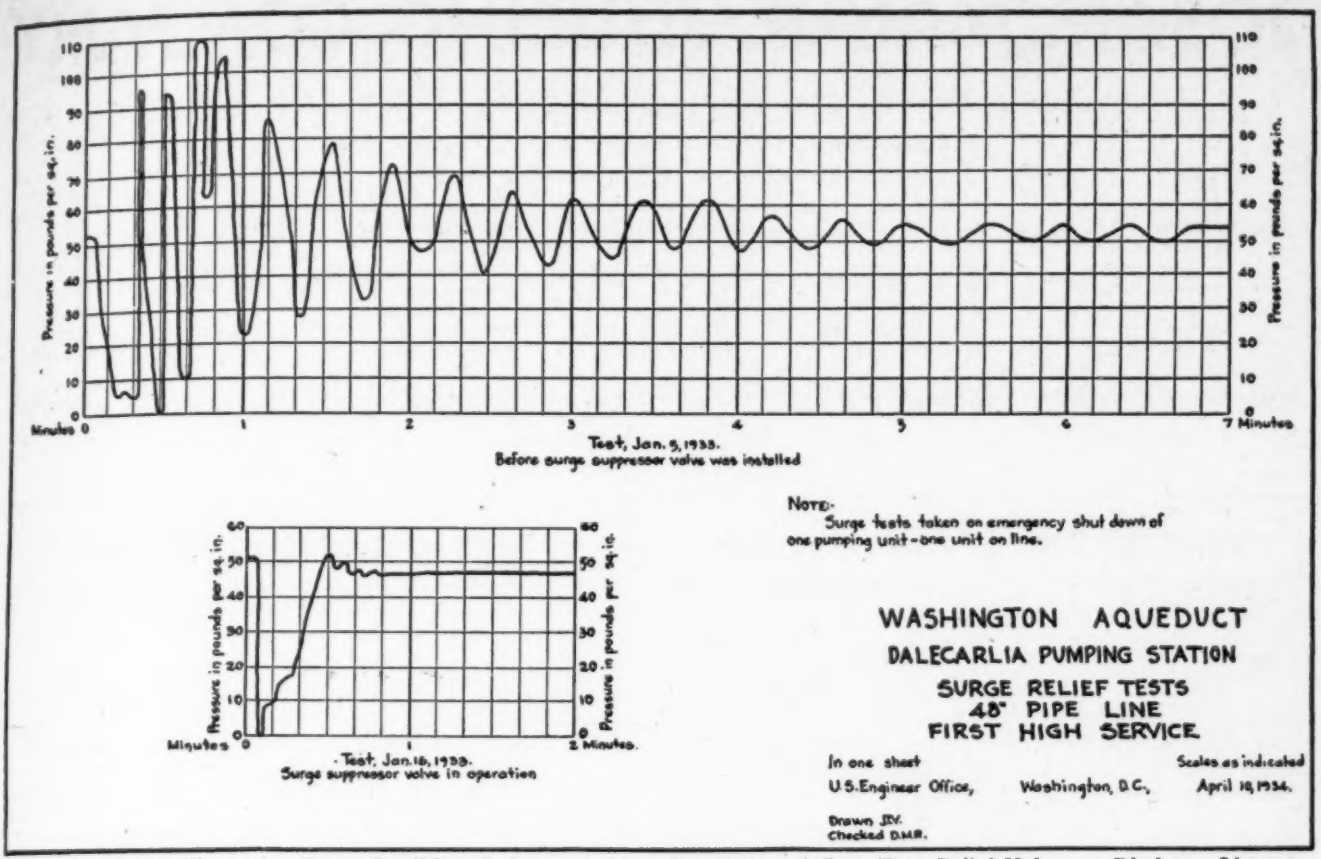
Pressure in pounds per sq. in.
Minutes
Test, Jan. 5, 1933.
Before surge suppressor valve was installed
Test, Jan. 16, 1933.
Surge suppressor valve in operation
NOTE:
Surge tests taken on emergency shut down of one pumping unit - one unit on line.
WASHINGTON AQUEDUCT
DALECARLIA PUMPING STATION
SURGE RELIEF TESTS
48" PIPE LINE
FIRST HIGH SERVICE
In one sheet
Scales as indicated
U.S. Engineer Office, Washington, D.C., April 18, 1934.
Drawn JSV.
Checked D.M.R.

Fig. 3.—Charts Illustrating Surge Conditions Before and After Installation of Cone Type Relief Valves on Discharge Lines

supernormal wave reached the station seven seconds after power failure. The results obtained by valve timing were therefore not considered satisfactory because these valves must protect pipe lines of concrete construction which were not designed to withstand the surge pressures encountered.

Further Studies on Surge Relief

Investigations of several methods of surge suppression in pipe lines were then made. It was decided to provide a relief valve on each pipe header in the pumping station. To make the installation it was necessary to provide an outlet from each of the three pump-discharge lines. This was accomplished by installing "Smith" tapping sleeves (Fig. 2) with 10 inch outlets. A 10-inch gate valve was bolted to each sleeve to provide emergency shut-off. The discharge from each surge relief valve was carried into the filtered water reservoir to prevent waste of purified water.

Before deciding upon size of valves to be used, calculations and field tests were made to arrive at the size of relief required. The field tests consisted of a series of surge tests relieved through different sizes of openings. This was done by providing a 12 inch valved opening on one of the pumping station headers. A series of tests was then made under variable pumping conditions with the several orifice plates bolted on the valve. The valve was of the quick opening, hydraulic type, manually controlled. A signal system was installed to insure proper timing of test valve opening. The field tests included surge relief through openings 2, 4, 6, 8, 10 and 12 inches in diameter. It was found that the 2 and 4-inch openings had very little effect in damping the supernormal surge pressure. The 6-inch opening did not damp the first supernormal wave but did damp out the succeeding waves. The 8-inch opening entirely damped or eliminated all supernormal waves. From the results obtained in the field tests it was decided to install 10-inch surge relief valves on each of the pump discharge lines. The chart (Fig. 1) shows the results of the tests made with the orifice plates under variable pumping conditions.

Automatic Cone Relief Valves Installed

The surge suppressor or relief valves installed are of the hydraulically operated, rotary plug type (Fig. 2), manufactured by the Automatic Cone Valve Company, now a division of the Chapman Valve Company. Since the valves meet open when the pressure drops in the pipe lines it was necessary to supply water pressure for valve operating from an independent source of supply. A 60-gallon residential supply water system was installed to insure an unfailing supply of water pressure to the three surge relief valves. The valves operate in the following manner: the normal pressure of the pipe line operates against a spring diaphragm pilot valve which admits control water pressure to the "closing" end of the hydraulic piston.

This holds the surge relief valve in the closed position. When a power failure occurs, the water in the pipe line flows away from the pumping station causing a subnormal wave in the line. This results in low pressure against the control diaphragm, which allows a spring to operate the pilot valve, which in turn allows high pressure control water to flow to the "opening" end of the hydraulic piston which opens the main surge relief valve. The opening action is very rapid, the entire operation requiring only from 1.5 to 2 seconds. The average duration of the first sub-normal wave in the Washington lines is approximately 8 seconds, thus the surge relief valve is wide open before the first super-normal return wave reaches the station. With the surge relief valve open, all succeeding supernormal waves are dissipated through the open valve. The pipe line now assumes a penstock condition and the surge relief valve must be closed very slowly in order to prevent setting up penstock surges. This is done by limiting the flow of control water to the "closing" end of the hydraulic piston. For successful results it was found that a 2-second opening and 2.5-minute closing of the surge relief valves entirely eliminated water-hammer or surges in the respective pipe lines.

Results

During the period of service since these surge relief valves have been in operation in the Dalecarlia Pumping Station several power failures have occurred. High speed pressure charts indicate, however, that pipe line surges have been entirely eliminated as indicated by typical records pictured in Fig. 3.

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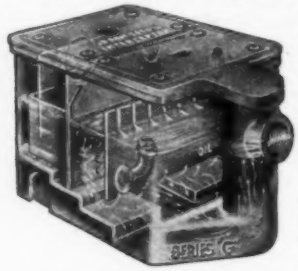

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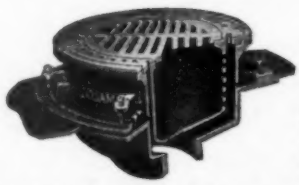

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WATER HAMMER CORRECTIVES

By RICHARD BENNETT, Hydraulic Engineer
City Engineer's Office, Phoenix, Arizona

PIPE LINES subjected to sudden shock or recurring vibration due to water hammer, become weakened and operate inefficiently. This destructive nuisance may also pull pipe hangers loose or create damaging leaks.

Destructive water hammer may actually be present in water lines even where its presence is not indicated by violent hammering and noisy vibration. For the most part this fact is not generally realized or recognized.

Cause of Water Hammer

If flow in a pipe is suddenly stopped, the energy built up by the flowing water produces a high pressure which may result in a terrific impact. This is caused by the non-compressible liquid (water) rebounding in the supply lines. This rebound impact is due to the sudden stopping of water flow every time a faucet or valve is closed. Power for operating hydraulic rams, which force water many times higher than the static head on the power water supply line, is thus generated by intermittent quick closures of valves attached to the ram.

In order to have conception of this force in small pipe, when water hammer occurs the pressure is increased by about 60 pounds per square inch above the flow pressure for each foot per second of sudden decrease of velocity of flow. This means that if a flow velocity of 10 feet per second is stopped instantly, a maximum water hammer pressure rise of (10x60) 600 lbs. per square inch may occur. This pressure is added to the normal static pressure at the point of impact.

Destructive water hammer must be eliminated to avoid the nerve-racking noise from which the term is derived; to reduce stress in the pipes; to safeguard plumbing fixtures; to avoid costly leaks and repairs; and to prevent operating delays.

Correctives

Relief from destructive water hammer may be accomplished by relief valves, but these can be used only in special cases. Relief can be obtained by air chambers, but the difficulty of keeping air in the chamber makes this method impractical under many conditions of operation. In many instances positive and permanent relief can be obtained by the installation of surge suppressors. These are sometimes given trade names such as shock absorber, water hammer arresters, etc. Just as the automobile shock absorber absorbs the bumps of the highway, so does a good surge suppressor cushion the terrific impact of water rebounding in the piping system.

Unless a surge suppressor is installed, the water backs up with terrific force and continues to bound and rebound in the pipe lines every time the flow of water is suddenly checked. With a good surge suppressor this pounding and hammering is overcome by absorbing and dispelling the shocks, and strain in the pipe is relieved.

In selecting a surge suppressor it is desirable that it afford protection from water hammer under all conditions of service; that it be easy to install; require no periodic adjustments; require little or no maintenance; that it operate in any position; that it be unaffected by hot water; and that it be reasonably priced.

Under some conditions it is possible to determine in advance the behavior of the surge suppressor, and a method for calculating the degree of relief from water hammer pressure for a given piping layout is obtained by the relation between useful volume of air in the surge suppressor for the various rates of discharge through the pipe line.

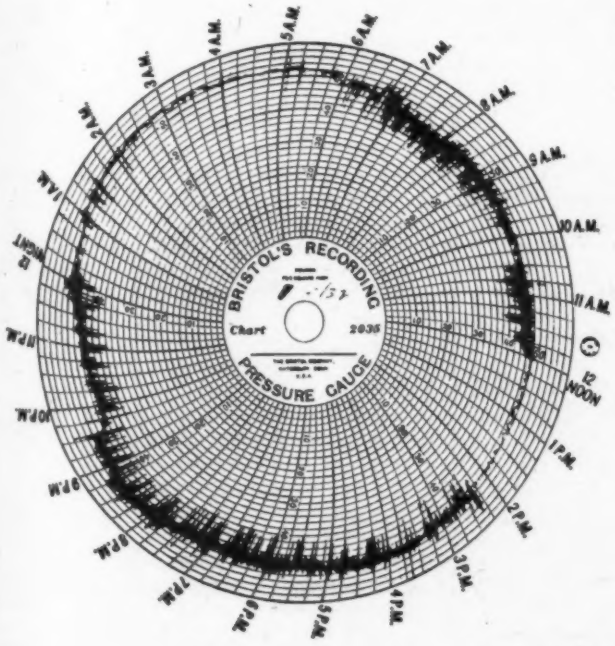
Theoretical considerations are generally to assume the discharge suddenly stopped by valve closure. This seldom occurs in actual practice. The size of the surge suppressor to be selected for each installation should be adequate to reduce the maximum water hammer pressure that can be caused by quick closure of any one valve or faucet.

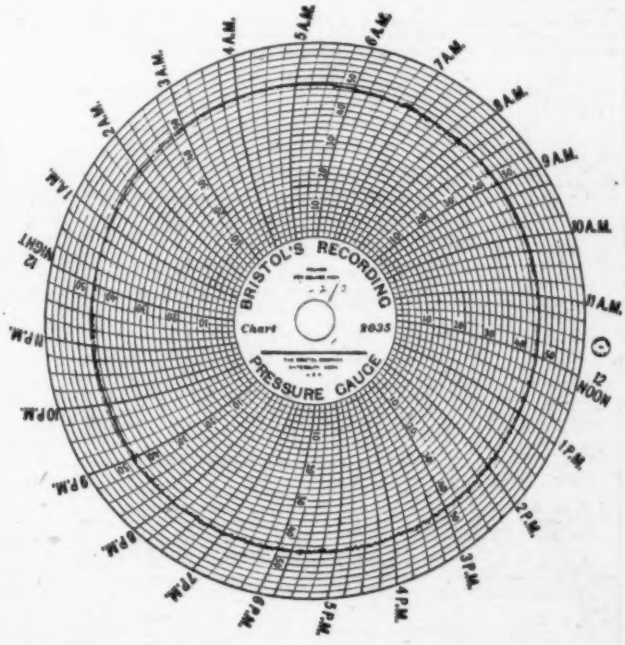
In Fig. 1 is illustrated the action of water hammer as recorded on a time-pressure diagram showing the incessant impact shocks and pressure fluctuations. The system is free of this shock effect (even though hammering may not be heard) only during those hours when no water is being drawn.

When an efficient surge suppressor is installed the time-pressure chart recording should look something like the chart shown in Fig. 2. A proper suppressor will quiet the water hammer by dissipating impact shocks and overcoming the pressure fluctuations

Surge Suppression Devices

Perhaps you have come to the conclusion of "Why not eliminate the source of the water hammer?" Quick closing valves are the cause of most of this trouble, but modern equipment of the present





A Story Told by Two Record Charts

Fig. 1—Reveals the incessant impact shocks and fluctuating pressures when water hammer is present.

Fig. 2—After the installation of a good surge suppressor the record chart should look something like this.

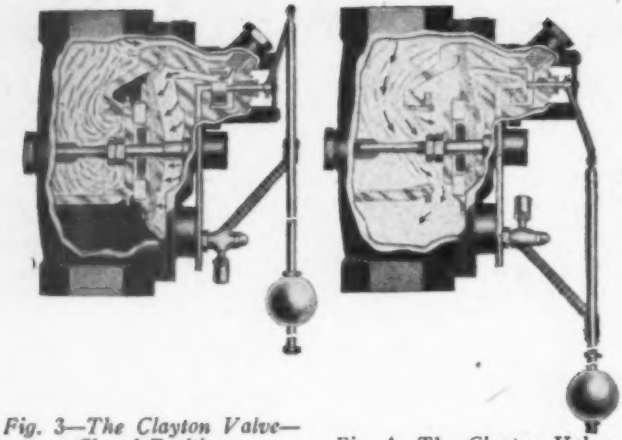


Fig. 3—The Clayton Valve—Closed Position
Is a quick closing valve designed to preclude hammer by uniform and governed rate of closure.

Fig. 4—The Clayton Valve—Open Position.
Always wide open or fully closed, functions well in rapid fillings of vats, tanks, etc.

day increasingly requires quick closing valves and water customers insist on quick closing faucets and fixtures, therefore water hammer troubles may be expected to increase, rather than decrease, in the future in most water works.

Valve manufacturers, as a group, have done very little to produce equipment to meet this situation, however, the Clayton valve has been designed for this purpose. It can be adapted to almost any type of flow control problem. Figs. 3 and 4 show this valve in the closed and open position. The arrows show that the valve is kept closed by water pressure on the back of the diaphragm. This valve can be furnished with an adjustable needle control for regulating the closing speed to meet any given condition. The illustrations show float control for rapid tank filling and smart shut off, but the manufacturer states that it can be adapted to remote, automatic, manual, elecric, or any type of control desired. Fig. 4 shows that when pressure behind the disc is removed the line pressure forces the diaphragm assembly away from the seat. This valve is always wide open or fully closed, and closes at a governed uniform rate to eliminate line shock when the shut-off occurs.

Relief Valves

Relief valves are sometimes used to eliminate water hammer but they can be used only in special cases, due largely to the spill of water which must be cared for, and do not operate except under

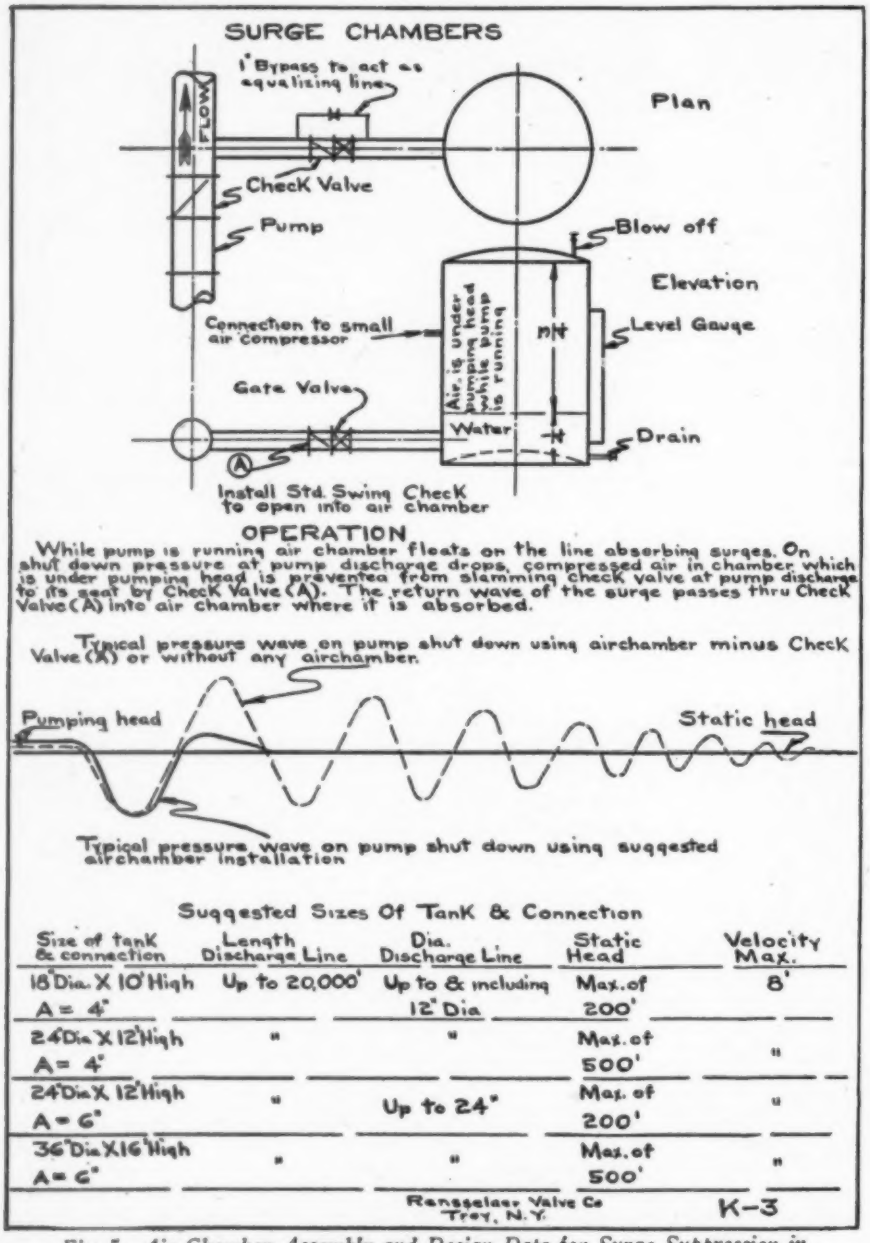

SURGE CHAMBERS
1" Bypass to act as equalizing line
FLOW
Plan
Check Valve
Pump
Blow off
Elevation
Connection to small air compressor
Air is under pumping head while pump is running
Level Gauge
Gate Valve
Water
Drain
A
Install Std. Swing Check to open into air chamber
OPERATION
While pump is running air chamber floats on the line absorbing surges. On shut down pressure at pump discharge drops, compressed air in chamber which is under pumping head is prevented from slamming check valve at pump discharge to its seat by Check Valve (A). The return wave of the surge passes thru Check Valve (A) into air chamber where it is absorbed.
Typical pressure wave on pump shut down using airchamber minus Check Valve (A) or without any airchamber.
Pumping head
Static head
Typical pressure wave on pump shut down using suggested airchamber installation
Suggested Sizes Of Tank & Connection
Size of tank & connection
Length Discharge Line
Dia. Discharge Line
Static Head
Velocity Max.
18" Dia. X 10' High A = 4"
Up to 20,000'
Up to & including 12" Dia
Max. of 200'
8'
24" Dia. X 12' High A = 4"
"
"
Max. of 500'
"
24" Dia. X 12' High A = 6"
"
Up to 24"
Max. of 200'
"
36" Dia. X 16' High A = 6"
"
"
Max. of 500'
"
Rensselaer Valve Co Troy, N.Y.
K-3

Fig. 5—Air Chamber Assembly and Design Data for Surge Suppression in Centrifugal Pump Operation.
Courtesy Rensselaer Valve Co.

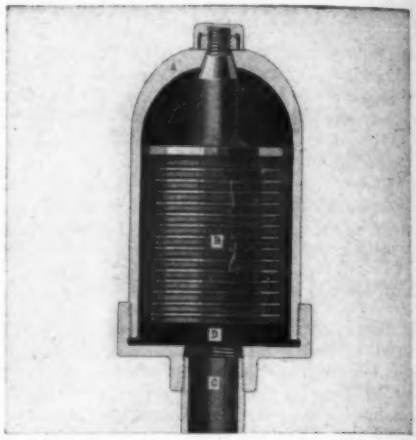


Fig. 6—"Wacor" Water Hammer Arrester
Position of bellows compression unit at time of normal pressure.

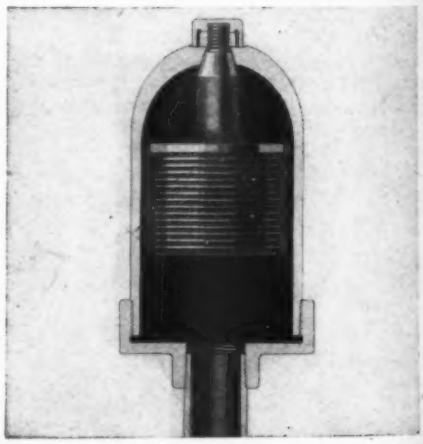


Fig. 7—"Wacor" Water Hammer Arrester
Position of bellows compression unit when absorbing hammer shock.

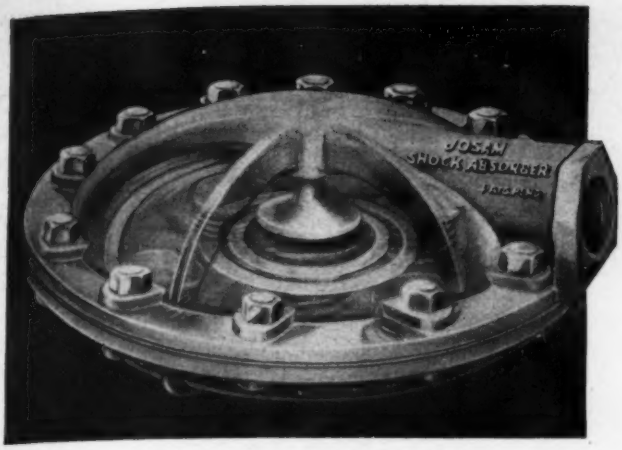


Fig. 8—The Josam Shock Absorber
Phantom view showing four coil springs in dry side of diaphragm chamber, which absorbs and dissipates the shock.

high surge pressure. However, many have secured satisfactory results from these devices at pumping stations and hydro-electric plants where water spill is not a problem.

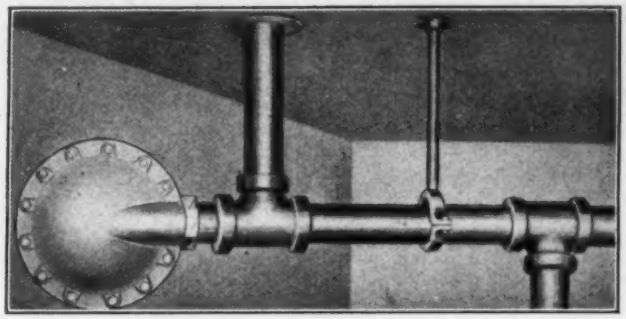


Fig. 9—A Josam Shock Absorber
(Installed at typical location point on the end of a long straight run of pipe.)

Air Chambers

Relief from destructive water hammer may be accomplished by air chambers, but the difficulty of keeping air in the chamber makes the air chamber impractical, unless given close attention, or air recharging can be automatically done with compressors.

Fig. 5 illustrates an air chamber assembly. When the pump is running the chamber of compressible air floats on the line absorbing or cushioning surges. When a pump shuts down pressure at the discharge drops instantaneously and then the back surge follows. Compressed air in the tank, which is under pumping

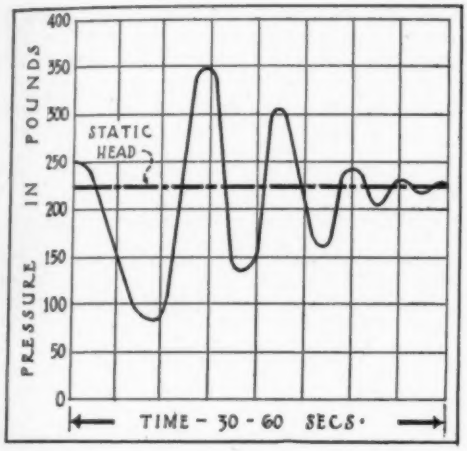


Fig. 11—The Effects of a Slow Closing Check
The lag in closing is responsible for the marked surge and hammer pressure.

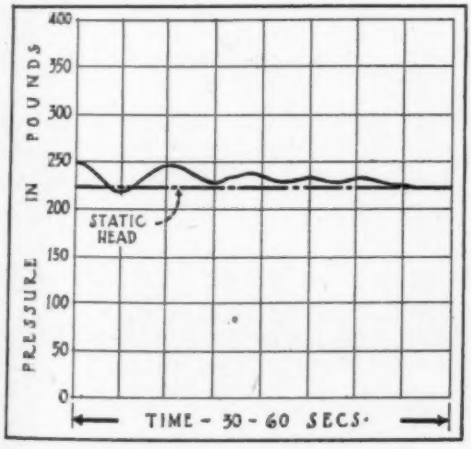


Fig. 12—The Effects of a Quick Closing Check
Showing the results of rapid closure when effectively timed ahead of the first rebound of the water column.

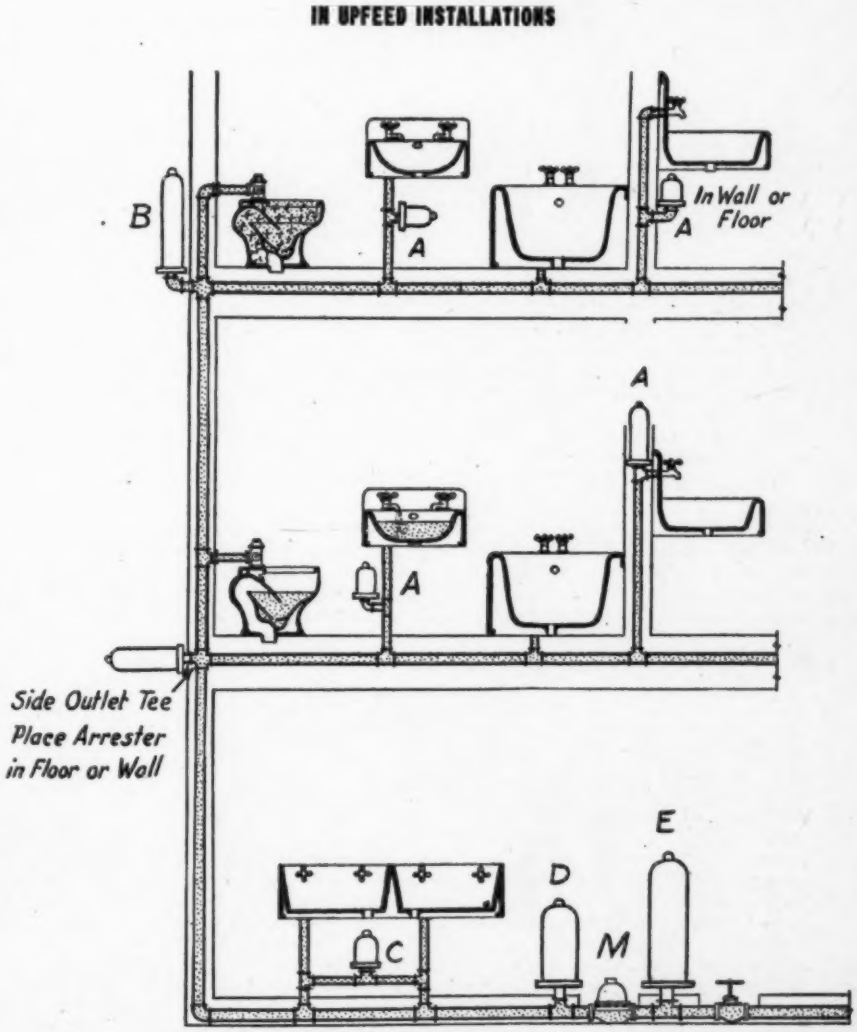


Fig. 10—Illustrating Other Typical Location Points for Shock Absorbers and Hammer Arresters

Fig. 13—The Smolensky Check
A wholly mechanical valve

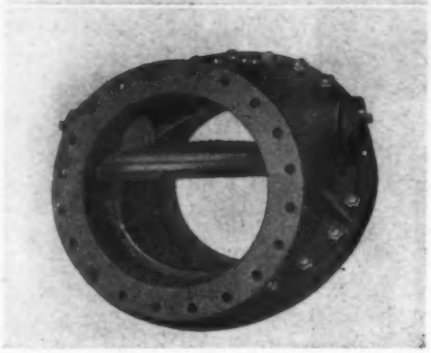


Fig. 16—Chapman's "Non-Slam" Check
Features the streamlined tilting disc, closing gradually to completion at instant of flow cessation away from pump.

Fig. 14—Interior of the Smolensky Check
Spring force enables this valve to close slightly in advance of cessation of flow away from the stopped pump.

originates in the municipal distribution system and affects the consumers' service line or plumbing installation.

Another surge suppressor for small piping systems is the Josam Shock Absorber, which is shown in Fig. 8. It operates on the diaphragm principle and is very efficient when properly sized to the individual problem. This suppressor absorbs shock by compression of four coal springs very much after the manner of the coil springs known as Knees in modern automobiles. The diaphragm moves out against these springs located on the dry side of the unit.

Location of Suppressors

Practice varies widely as to the proper installation point for surge suppressors; some will place a suppressor at the end of all long runs of pipe; others install at the end of a battery of fixtures, but it seems agreed that it should be placed *as near to the valve causing the water hammer as is permissible.*

It is desirable to place the suppressor so that the opening is at the bottom if possible. This will avoid hazards from sediment being washed into the casing. Wherever a greater capacity is required to reduce water hammer pressure than can be furnished by a single suppressor, any number can be placed in the pipe line, either in scattered positions or together at one fitting.

Figs. 9 and 10 show typical installation points for suppressors of this general type.

head, is prevented from slamming the check valve on the pump discharge line to its seat by the functioning of check valve (A). The return wave of the surge, however, can pass through the check valve (A) into the air chambers where it is markedly cushioned and gradually absorbed during gradually diminishing surges.

For most all cases of water hammer, of the type caused by quick closing valves on all but the largest lines, a surge suppressor which may be attached to the pipes and operate automatically without maintenance is to be preferred. Of this type the "Wacor," shown in Figs. 6 and 7 is very reliable. This suppressor has been thoroughly engineered for small piping systems, the manufacturer having financed an extended research program in the hydraulic laboratories of the University of Wisconsin, where all possibilities of this equipment were rather thoroughly explored.

"Wacor" Water Hammer Arrester is manufactured in a number of sizes for pipe lines up to 10-inch in diameter. It is a combination mechanical-pneumatic type of absorber constructed with a closed metal bellows or compression compartment. The latter is filled with a special compressible emulsion so that air can neither escape nor be absorbed by the water. It is particularly adapted to all ordinary house services where water hammer exists or where high pressures engendered by rapid valve closure are damaging piping and fixtues.

When this suppressor is put on the line the sealed (compression chamber or bellows (containing the emulsion) is slightly compressed as the water pressure is turned on the system. This is shown in Fig. 6, with the bellows at resting position. If now a valve or faucet is opened and water flows through the pipe, the bellows expands somewhat due to the reduction of the pressure at its base. As the valve or faucet is closed the velocity of the water in the pipe line is reduced, resulting in an increase of pressure. This compresses the bellows, resulting in an increase of pressure on the emulsion sealed within the bellows. The pressure inside and outside of the bellows thus becomes equalized. Work done in compressing the fluid emulsion within the bellows is responsible for the absorption or damping of the hammer pressure in the pipe line to which the arrester is connected. This is shown in Fig. 7, and illustrates the position of the bellows, when absorbing the hammer shock.

This type obviates the need for the attention which air chambers require. They are used with quick action valves and high velocities of flow, and can be used where water hammer pressure

Water Hammer with Centrifugal Pumps

The use of centrifugal pumps presents a major problem in the control of surge water and minimizing of water hammer. When the power is shut off the water in the discharge line reverses its direction of flow and if not controlled will cause reversal of pump and motor.

The installation of the flap type check valve with centrifugal pumps increases the effect of surge waves and water hammer, if not actually being responsible for such. Ordinary check swing valves, due to slamming, cause abnormal disturbances in the pipe lines. Slam leads to serious trouble because of the resulting vibration of pipe lines and adjacent structures, opening up the pipe

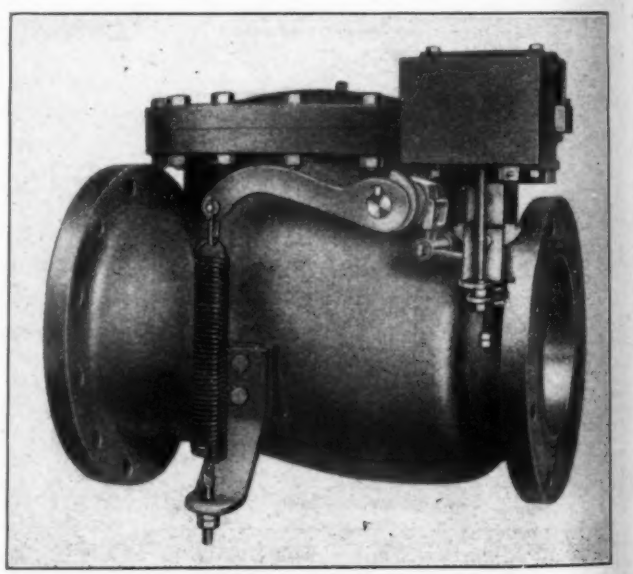
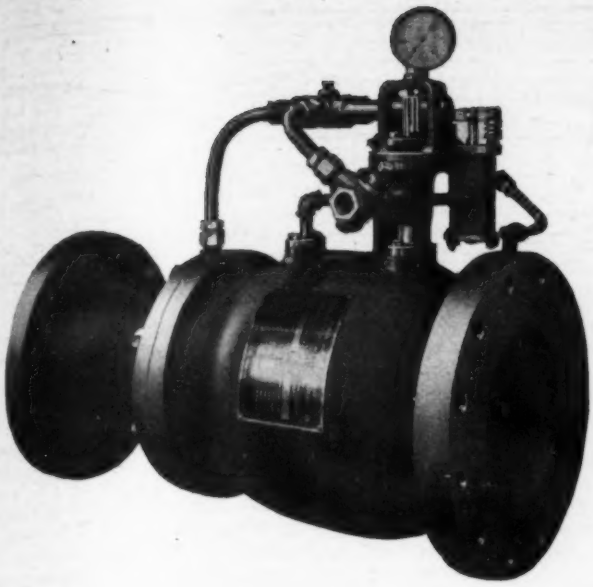
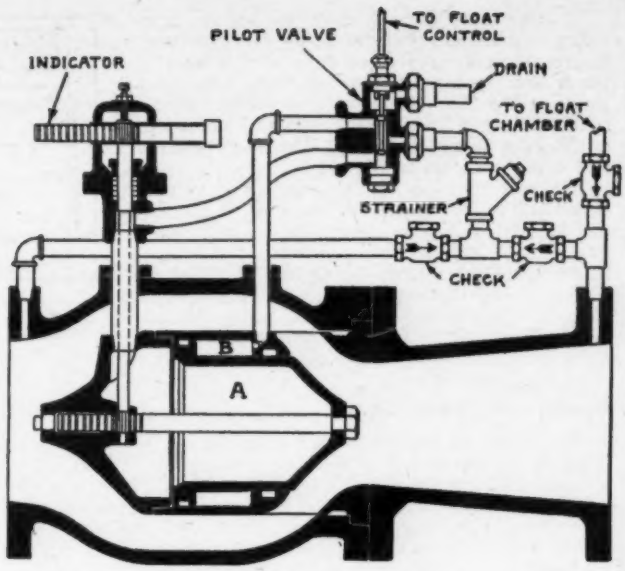


Fig. 15—The Rensselaer Automatic Power Check
Features low-friction clear-way and quiet spring loaded closing of the flap ahead of cessation of flow away from the stopped pump





Pelton's Larner-Johnson Check Valve

Fig. 17—Exterior of this automatic needle-type check.

Fig. 18—Sketch revealing design and functioning of the valve.

Fig. 19—The Pelton Surge Suppressor A high grade relief valve for use in conjunction with automatic check valves.

joints. The resultant water hammer frequently ruptures the pipe line. The common swing check valve is fundamentally wrong in its design to be of use for such service.

Check valves may be grouped into two general classes: (a) slow closing and (b) quick closing.

Most slow closing valves are, however, impractical, even though theoretically correct. The action of this type of valve with respect to water hammer may be shown by the illustration in Fig. 11. In practice there may be little or no audible water hammer with this type, but as indicated, there is a serious pressure rise due to the surge which may be disastrous to the pipe lines and fittings.

A check valve should generally be of a type that closes *before* the pressure reverses from the immediate low to the quickly ensuing high. Many have found that this is the only type that will give proper service. The quick closing check valve provides for eliminating surge shock at the valve seat, and quickly returns the surge wave to static pressure before any appreciable surge oscillation can be set up in the discharge line. All discharge lines, especially of the larger diameters, are at least to some degree elastic and will permit so-called harmonic surges to develop. When the discharge column of water is halted before a reversal of flow takes place, these surges will not cause a dangerous pressure rise. The action of the rapidly closing type of check valve, with respect to ensuing water hammer, may be illustrated as shown in Fig. 12. These two pressure recordings (Figs. 11 and 12) show that the pressure rise has been reduced from about 50 per cent excess head to about 10 per cent over the static pressure through the effective timing of closure of the automatic check.

The Smolensky Check

One type of check valve used for this purpose is the Smolensky check valve, which is illustrated in Figs. 13 and 14.

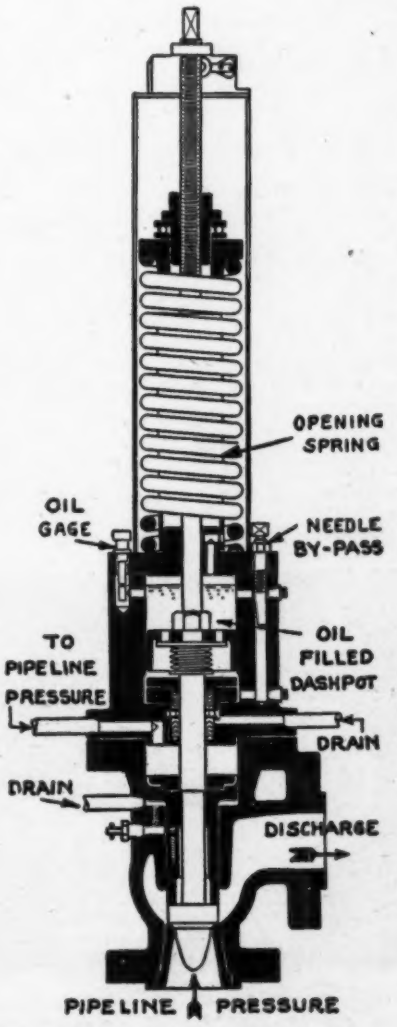


Fig. 20—The Pelton Surge Suppressor Sketch revealing working parts and functioning of this surge dissipating unit.

This valve is designed to close just a little in advance of minimum pressure at the pump, so as to insure absolute freedom of danger of reversal of pump and motor. It also prevents mechanical shock at the check valve for the spring action is counterbalanced by the back pressure against the diminishing pump discharge. The mechanism of this valve is shown in Fig. 14.

The seat position of the Smolensky valve is dependent entirely upon the velocity of the flow and the action may be understood by reference to the homely analogy of a laborer following a loaded truck up a steep incline. By chocking the wheels at the slightest tendency to stop, a small stone is sufficient to hold the load from reversing. Allow the truck to fall back a few feet and the truck load will be in danger, since its stopping is much the more difficult.

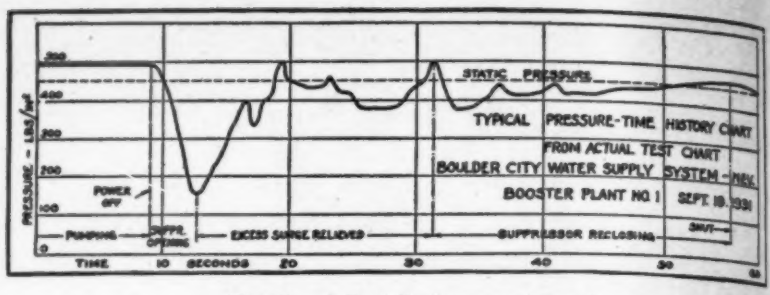


Fig. 21—A Real Performance Record
Showing the result of combination of automatic check and Pelton Surge Suppressor on a heavy duty job under 490 lbs. static head. This race was won in approximately 50 seconds flat.

Rensselaer's Power Check

Fig. 15 shows the Rensselaer quiet-closing power check valve. This check operates with an electric solenoid. When the pump is started the swing check is opened and held out of the flow in a locked position. Instantly that the power is released the solenoid automatically releases the swing check and the power of the spring instantly closes the check ahead of the reversal in direction of flow.

Chapman's Tilting Disc

Fig. 16 illustrates the exterior and interior of the Chapman non-slam tilting-disc check valve. This type of check closes with a minimum of slam. Friction losses are also very substantially reduced in the design. The disc is pivoted just above its center, which results in a cushioning effect resulting while closing. This is due to the fact that the portion of the disc above the pivot partially balances the portion below. The seat and disc rings are beveled and the disc drops into the seat in the body with a closing action which gives a further cushioning effect. This valve in closing reaches its seat at exactly zero velocity in the line. The angle of the seat is so incline that the distance the disc must travel from its wide open position to its seat is reduced to the minimum consistent with good design.

Larner-Johnson Check

Fig. 17 shows the exterior of the Pelton-Larner-Johnson check valve, and Fig. 18 shows how it functions.

This check is normally automatic in operation but may be arranged for manual control. With the control equipment which is built into this type of check valve the time of closing may be regulated to best suit local conditions. It is designed for installation on the discharge side of a centrifugal pump, its best function being to close at the instant of power failure and to prevent both reversal of the pump and motor and wastage of pumped water.

Pelton Surge Relief Valve

In many cases of operating centrifugal pumps, surge and water hammer cannot be eliminated by the mere installation of a check valve alone regardless of type. In such cases it is also necessary to install additional equipment such as an air tank, relief valve or such. For difficult situations one of the best known pieces of equipment for this purpose is the Pelton Surge Suppressor, shown in Figs. 19 and 20. This surge suppressor is essentially a high grade relief valve, designed for use with a check to relieve surge pressure in a pump discharge line incident to pump shutdown. It may be operated either by water pressure, solenoid or mechanical interconnection with the check valve. To permit a sufficiently rapid closure of the check and thereby prevent dangerous reversal of the pump after the power shut-off, the surge suppressor is essential to relieve the resulting pressure surges. The surge suppressor *opens with the drop in pressure* following shutdowns, remaining open to relieve the surge which follows. It then automatically closes at an adjustable rate.

The action of the Larner-Johnson Check Valve and the Pelton Surge Suppressor in combination are shown in the results obtained on the accompanying time-pressure diagram (Fig. 21) of the Boulder Dam water supply to Boulder City. Operating under a static pressure of about 490 pounds, the time-pressure diagram (Fig. 21) shows that it took about 50 seconds only for the pressure head to become normal static head after pump shutdown, during which interval the rise in pressure was not more than 10 pounds above static.

Studying and Recording Surge Conditions

In actual operating practice it is seldom that any two cases of surge or water hammer are identically alike. The simpler cases of surge in building pipe systems may usually be overcome with the low cost type of surge suppressors previously shown. With the more complicated cases, especially those affecting water distribution systems, the conditions become very involved and it is usually necessary to make a complete survey of the actual facts pertaining to each individual case before it can be properly handled. It is necessary to determine the amount and intensity of water hammer and thereafter take new records in order to determine the results obtained from equipment installed, or other corrective measures applied.

For this purpose it is essential to employ equipment for recording pressure-time diagrams of the disturbance. Fig. 22 shows Bachrach's Chronomatic Drum, which gives a pressure-time diagram, revealing clearly the pressure pulsations in the pipe line during a certain time interval. Fig. 23 shows this equipment in carrying case for ready portability. This is a time-pressure indicator originally designed for testing high-speed diesel engines. It has unrestricted speed selectivity and instantaneous speed indication. The operation is simple and requires no skill or special training. The time-pressure diagram for the Boulder City line was taken with this equipment.

Few engineers have had wide contact with problems calling for relief from water hammer in pipe lines or piping systems. The present literature on the subject is neither broad nor inclusive, being largely devoted to the extreme technical and theoretical phases of the subject. On this account it has been my purpose to confine this discussion to a few practical considerations.

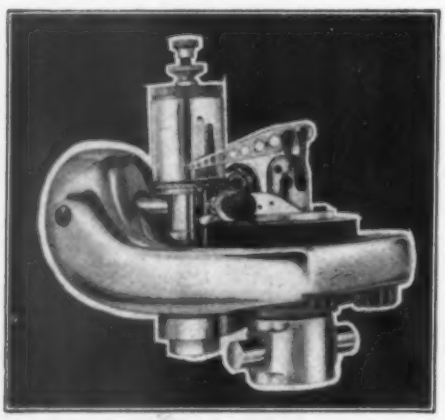


Fig. 22—Bachrach's Chronomatic Drum
Its use provides the all important time-pressure chart in studying water hammer and attainments resulting from corrective measures and functioning of equipment.

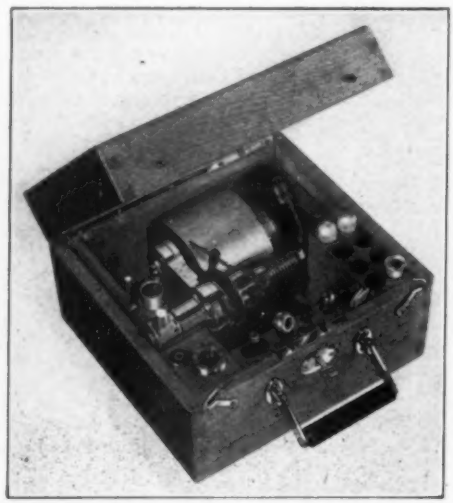


Fig. 23—Bachrach's Portable Recorder
Is compact and useful in surge study on pipe lines and distribution systems.

CUTTING CAST IRON PIPES

By Unique Method Developed in Atlanta

By W. M. RAPP

Late Superintendent, Construction and Distribution, Atlanta, Georgia

In brief, the method of pipe cutting, to be described, consists of drilling a circle of holes around the pipe and placing tapered wedge pins in each. Then, driving these up in sequence until the split once started, from hole to hole, travels the circumference of the pipe rapidly. The result is a "ripped" line of neat breaks from hole center to hole center.

The following has been drawn from a report by J. N. Eley, consulting engineer, which is a first-hand account of one pipe-cutting job done for Buford, Hall & Smith, Atlanta contractors, in connection with the construction of one of Atlanta's new sewage treatment plants.

The pipe cut was a standard length of 54 inch Class B Cast-Iron pipe produced by U. S. Pipe & Foundry Co.

For the job, the contractors used their truck mounted Worthington air-compressor unit, having a capacity of 105 cfm. at 100 lbs. pressure. The balance of the needed equipment was loaned by the Atlanta Water Department, and consisted of the following:

An Ingersoll-Rand, Size B, Non-Reversible Air Drill, mounted in a frame with hand feed, chains and toggle-level locking device, designed by Mr. Rapp. (See picture.)

An adjustable pipe scriber; two track-levers, used in pinch-moving freight cars, for turning the large pipe; the required number of round tapered pin wedges, having opposite faces slightly flat for reasons later obvious; two sledge hammers.

(Note—The same equipment used for cutting the 54 inch pipe is also used on all pipes between 12 and 60 inch diameters.)

The crew making the cut consisted of: One compressor operator, one handy man, three colored laborers. One of the latter was a veteran employee of the Water Department, but none of the remainder of the crew had ever seen the method used before.

The Procedure

Because of the boggy nature of the ground, the length of 54 inch pipe was first rolled onto 8 x 8 pine skids. This facilitated turning it with the freight car moving-levers through various degrees, to make scribing, drilling and wedge driving easier. With the adjustable scribe a drill guide line was scribed around the exterior circumference and centers, for the 1 inch holes to be drilled, were marked with a center punch.

The air operated drilling machine was then set up on the pipe and connected to the compressor air lines. The drilling then proceeded around the scribed line. For convenience and neater and faster work, by inexperienced workmen, the pipe was turned about 33 degrees, at intervals, to keep the drill in a more nearly vertical position.

Wedge Driving

The drilling completed, pin-wedges were tightly set in 33 of the 45 holes by hand hammer. The flat edges faced with the line. Then began the sledging, or the driving-up operation. Starting with pin No. 1, full force blows were struck each odd number pin in sequence—3, 5, 7 . . . 33. From pin 33 the driving-up was reversed with the sledging of the even number pins, 32, 30, 28 . . . 2, in sequence. After two minutes (less 5 seconds) of this procedure a fracture, approximately 12 inches long, showed up from pin 5 to pin 8. After 45 seconds more of sledging the fracture had extended half-way around the pipe. The pipe was then pinch-rolled forward and pins were inserted in the 12 remaining holes, thus brought into position. Sledging of alternate pins was resumed in sequence, as before, and after another minute (plus 3 seconds) the end bell dropped down and the job was complete.

How successful the operation was, is shown in the accompanying pictures revealing the clean and regular fracture straight through the 1.9/16 in. pipe walls, and departing but little from either side of the scribed line. No horizontal fractures, radial to the holes, appeared. The absence of chipping and projection is likewise worthy of note.

Time Consumed

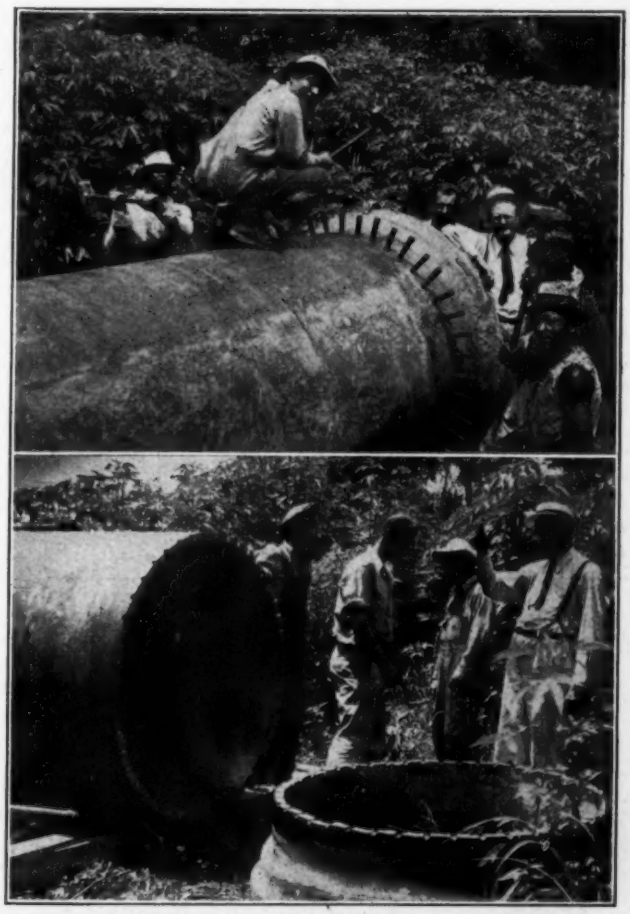
A careful stop-watch record was kept of the time consumed in the several operations. A recapitulation follows:

Operation	Min.	Sec.
Scribing (drill line)	3	55
Rolling pipe (total)	6	14
Center punching (on line)	10	42
Setting Machine (on line)	5	57
Drilling (45—1 in. holes)	35	56
Backing and resetting drill	26	53
Removing machine (from pipe)	0	41
Setting Tapered Wedges (45)	2	10
Driving-up wedges	3	48
Throwing the bell	0	15

Total consumed time—1 hour, 36 min., 31 sec.

Costs:

Compressor operator ($1.00 hour)	$1.61
Handy man (75 cents hour)	1.21
Two laborers (40 cents hour)	1.29
One laborer (52 cents hour)	.84
Total labor cost	$4.95
2.41 gals. gasoline at 22 cents gallon	0.53
Total cost of cutting 54-in. Class B pipe	$5.48



Drilling Completed and Pin-Wedges Set Ready For the Boys to Let Loose With the "Persuaders." After 3 Minutes and 48 Seconds of This Staccato, Here's the Result Below.

UNITED STATES PIPE AND FOUNDRY CO.

General Offices: **Burlington, New Jersey**

SALES OFFICES

Philadelphia, New York, Birmingham, Chicago, San Francisco, Boston, Pittsburgh, Buffalo, Cleveland, Kansas City, Minneapolis, Dallas, Seattle, Los Angeles

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SUPER-DE LAVAUD CENTRIFUGALLY CAST IRON PIPE
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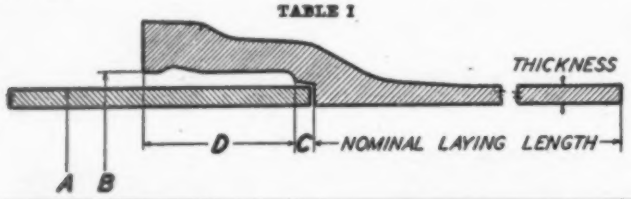
Super-deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3" to 24" and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-deLavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length 12-Foot Length: Weight of Pipe Pounds	12-Foot Length: Weight Per Foot Including Bell	18-Foot Length: Weight of Pipe Pounds	18-Foot Length: Weight Per Foot Including Bell
3	150	.33	140	11.8	210	11.7
3	250	.36	155	12.8	230	12.7
4	150	.34	195	16.4	285	15.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	26.3	460	25.5
6	250	.43	350	29.3	515	28.5
8	150	.42	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.3	935	51.8
10	200	.53	700	58.3	1025	56.8
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1180	65.6
12	200	.57	905	75.4	1325	73.7
12	250	.62	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length 12-Foot Length: Weight of Pipe Pounds	12-Foot Length: Weight Per Foot Including Bell	18-Foot Length: Weight of Pipe Pounds	18-Foot Length: Weight Per Foot Including Bell
14	100	.48	920	76.5	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1190	99.0	1735	96.3
14	250	.69	1320	110.0	1930	107.3
16	100	.52	1130	94.2	1645	91.4
16	150	.60	1320	110.2	1935	107.4
16	200	.68	1490	124.1	2175	120.7
16	250	.75	1635	136.1	2390	132.7
18	100	.56	1365	113.8	1990	110.6
18	150	.65	1595	132.8	2330	129.6
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.58	1585	132.0	2305	128.0
20	150	.68	1860	155.0	2720	151.0
20	200	.78	2125	177.1	3105	172.4
20	250	.88	2365	197.1	3465	192.4
24	100	.64	2085	173.8	3035	168.6
24	150	.76	2480	206.8	3630	201.6
24	200	.88	2855	237.8	4170	231.6
24	250	1.00	3200	266.8	4690	260.6

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per Foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.48	8	14.21
	Standard	18	4.50	.38	8	15.34
	X-strong	18	4.50	.48	8	18.91
	XX-strong	18	4.50	.52	8	20.29
	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.49
	XX-strong	18	5.56	.53	8	26.15
	Standard	18	6.63	.43	8	26.13
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.72
	Standard	18	8.63	.50	8	39.85
8	X-strong	18	8.63	.56	8	44.20
	XX-strong	18	8.63	.60	8	47.22

THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

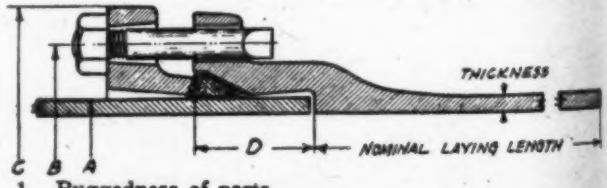
Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	18	4.50	.29	8	13.75
5	18	5.56	.33	8	19.05
6	18	6.62	.38	8	26.22
8	18	8.62	.44	8	39.82

THE U. S. JOINT

The U. S. Joint embodies the more favorable features of certain other types of mechanical joints and was developed and patented by the United States Pipe and Foundry Company after considerable study and research. It is adaptable to both Super deLavaud Centrifugal Pipe, and to pit cast pipe and fittings and these may be interchanged one with another in the laying of a line without the need of an adapter. The accessories, which consist of follower ring, gaskets and bolts are all interchangeable.

It possesses the following salient advantages:

Write for "U. S. Joint Pipe and Fittings" Catalog.



1. Ruggedness of parts.
2. High resistance to corrosion since all of the joint accessories are of the same material—cast iron.
3. Maximum joint deflection without leakage.
4. Great resistance to the flow of electric currents.
5. Ease of assembly—needs only one wrench.
6. Only one gasket per joint.
7. Excellent qualities as an expansion joint.
8. Tightness under high pressures of gas or water.
9. Connection to plain end existing pipe line without use of adapter.

HYDRAULIC DEVELOPMENT CORPORATION

MANUFACTURERS OF HYDRO-TITE—A SELF-CAULKING COMPOUND
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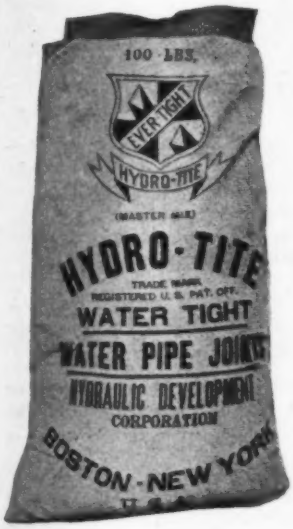

Properties of HYDRO-TITE

HYDRO-TITE is a black powder composed of selected inert minerals. When melted and allowed to cool, it becomes a strong, tough, metallic mass. Compressive strength is 6,000 lbs. per square inch and its tensile strength is over 650 lbs. per square inch.

Manufacture of HYDRO-TITE

HYDRO-TITE is made in an up-to-date factory with modern machines and by efficient methods. Constant inspection, alert supervision and many years of research by some of the best trained chemical scientists combine to make HYDRO-TITE the leader in its field. This makes possible our continued use of the slogan—"MORE THAN 30 YEARS WITHOUT A FAILURE."

HYDRO-TITE Features

Self-Caulking: HYDRO-TITE is melted by a small fire and nothing is added to make it liquid. When poured into a joint it immediately solidifies upon contact with the metal and bonds to both the surface of the bell and the spigot for the entire length of the joint. HYDRO-TITE requires no caulking.

Self-Sealing: HYDRO-TITE joints are, under normal conditions, perfectly tight when pressure is first applied. Any leak or seep from a new joint will soon be stopped by the self-sealing quality of HYDRO-TITE. Even leaks occurring when pouring over-heated HYDRO-TITE will seal themselves within a day or two. "Less leakage from the start and quicker sealing qualities in case of small leakage."

Ready for Immediate Use: There need be no waiting time after pouring a joint with HYDRO-TITE. It solidifies at once upon contact with the pipe and is ready for regular pipe service.

RESISTS VIBRATION: HYDRO-TITE can be used anywhere. It is in service on pipe lines carried over bridges subjected to heavy automobile trucking, trolley cars and continuous railway traffic.

DRY BRAIDED FIBREX

A Sanitary Packing used in Jointing Bell and Spigot Pipe for Water Mains—Sewer Mains—Soil Pipe.

FIBREX is the answer to the constant demand by Sanitary Engineers for a packing which will not breed bacteria when used in water mains. Fibrex is a paper packing treated with a special water repellent which keeps the Fibrex sterile and prevents it from disintegrating. It has a hard twisted core with a basket weave covering and packs in a joint exactly the same as braided jute.

FIBREX is 30% lighter in weight than dry braided jute and is put up in 60-pound reels. Each reel will take the place of over 90 pounds of braided jute and the cost per pound is approximately the same for both Fibrex and jute. This effects a 30% saving in cost.

FIBREX was designed for use with Hydro-Tite and other self-caulking compounds. However, it is entirely suitable for joints made with lead, also for Sani-Tite and other asphalt sewer joint compounds.

Thousands of pounds of dry braided Fibrex are already in service on water lines throughout the country. It has the approval of the War Department at Washington, several different Area Engineer Offices of the War Department, the Departments of Public Health in some of our larger states and numerous Water Departments.

Laboratory tests have been made by Skinner & Sherman, Inc., Chemists and Engineers, Boston, Mass., and their report shows that Fibrex does not breed bacteria, as is characteristic of jute, in both sterile and contaminated water.

FIBREX is made in ⅜", ½" and ⅝" sizes The ½" size is used on nearly all joints. The ⅜" and ⅝" sizes are used on thick or thin joints, as in case of some specials or changing over from one class pipe to another.

The Atlas Mineral Products Company of Pennsylvania

Mertztown, Penna.

THE House Jointing Materials

*ATLANTA 3, Ga., 610 Red Rock Bldg.
*CHICAGO 1, Ill., 333 No. Michigan Ave.
*DALLAS 5, Tex., 3921 Purdue St.
*JACKSONVILLE 5, Fla., 1463 Talbot Ave.
*DETROIT 2, Mich., 2970 W. Grand Blvd.
*KANSAS CITY 2, Kan., 1913 Tauromee Ave.
NEW YORK 16, N. Y., 280 Madison Ave.
PITTSBURGH 10, Pa., 4656 Old Boston Rd.
TORONTO, Ont., McRae Engineering Equipment, Ltd., 11 King St., West

THE ATLAS MINERAL PRODUCTS COMPANY OF CALIFORNIA

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*LOS ANGELES 12, California
817 Yale St.

*SEATTLE 14, Washington
H. D. Fowler Company
P. O. Box 3084

A Tegul Product

MANUFACTURERS OF Tegul-MINERALEAD JOINTING COMPOUND

For BELL and SPIGOT PIPE

Tegul-MINERALEAD is a radically different jointing compound with advantages not matched in total in any other product for its purpose. Its sulphur base includes, as a plasticising agent, a special olefine polysulphide which contributes these advantageous properties: GREATER ADHESION TO METALLIC AND CERAMIC SURFACES • HIGHER RESISTANCE TO VIBRATION and to MECHANICAL SHOCK and TEMPERATURE CHANGES • GREATER PLASTICITY and LOWER COEFFICIENT OF EXPANSION. Using *Tegul*-MINERALEAD you may expect:

SPEED — *Tegul*-MINERALEAD melts, pours and sets quickly and uniformly (a factor in reducing labor costs). Joints show less than usual initial leakage and backfilling may start at once, thus hastening removal of traffic hazards which arise from open trenches.

CONVENIENCE — Molded in 10 lb. ingots, *Tegul*-MINERALEAD is easier to handle, ship and store. The ingot is impervious to moisture, so may be stored outdoors in any weather. Since there can be no change of composition in an ingot, *Tegul*-MINERALEAD reaches you as correctly mixed as when it left our factory.

ECONOMY — *Tegul*-MINERALEAD weighs only 1/5th as much as lead (and goes 3 times as far) saving in shipping costs. 5 ingots to cartan makes a handy package. It melts, pours and sets quickly, needs no caulking or deep bell holes and requires no skilled labor. The sum of *Tegul*-MINERALEAD'S advantages makes it a money-saver too.

RESISTANCE TO SHOCK — Higher resistance to mechanical and thermal shock promises permanently tight joints. Lines laid with *Tegul*-MINERALEAD in every kind of terrain and meeting every kind of punishment, have served for years without need of attention.

AVAILABILITY — *Tegul*-MINERALEAD is stocked at conveniently located points and is usually available on short notice. Using *Tegul*-MINERALEAD helps conserve lead, a strategic war metal.

HOW *Tegul*-MINERALEAD IS USED

MELTING — *Tegul*-MINERALEAD melts at 248°F., requiring only a slow fire. Care should be taken to avoid direct contact with flame and overheating, which tends to cause the compound to thicken. Best results are had by using furnace designed by the manufacturers of *Tegul*-MINERALEAD.

YARNING—The pipe at Bell and Spigot must be clean and free from accumulations of oil, tar and grease. If jute is employed, it should be the dry, braided type.

POURING — See that joints are clean. Use mud on asbestos runner to prevent adhesion to the *Tegul*-MINERALEAD and to seal any leaks. Pour the melted compound slowly through a high pouring gate, using ladles or pouring pot of sufficient capacity to fill the joint at one operation. Add whole or half ingots to replace *Tegul*-MINERALEAD used. It is not necessary to wait for complete melting before pouring more joints. Cut off pouring gate when compound has solidified. Remove runner and joint is complete.

POURING WET JOINTS—Follow same general procedure as above except that runner must be held away from bell at bottom of joint to provide outlet through which the *Tegul*-MINERALEAD can drive out the water. When the compound flows freely through this opening, close with clay and continue pouring until gate is full. Better results are obtained when *Tegul*-MINERALEAD is heated to just below the thickening point.

This table shows relative amounts of *Tegul*-MINERALEAD, as against lead, and amounts of braided jute required to make approved joint in A.W.W.A. Standard Pipe.

Nominal Inside Diameter of Pipe In Inches	Pounds of *Tegul*-MINERALEAD per Joint Using 1 Ring Braided Jute	Pounds of *Tegul*-MINERALEAD per Joint Using 2 Rings Braided Jute	Pounds of Lead per Joint	Pounds of Braided Jute Using 1 Ring	Pounds of Braided Jute Using 2 Rings
4"	1.9	1.6	7.5	.10*	.20*
6"	3.0	2.4	10.25	.13*	.25*
8"	4.6	3.9	13.25	.17*	.34*
10"	5.5	4.7	16.	.20*	.40*
12"	6.5	5.6	19.	.24*	.48*
14"	7.5	6.4	22.	.27*	.54*
16"	10.1	8.7	30.	.45†	.90†
18"	11.7	9.7	33.	.51†	1.02†
20"	12.6	10.8	37.	.57†	1.13†
24"	14.9	12.8	44.	.66†	1.32†
30"	18.4	15.8	54.	.83†	1.65†
36"	22.2	19.	65.	.92†	1.83†
42"	29.5	26.5	75.	1.13†	2.25†
48"	33.3	30.3	85.	1.28†	2.55†

* Use ½" jute on this size
† Use ⅜" jute on this size

Add 15% to above *Tegul*-MINERALEAD amounts, if pipe to be used has no bead on the spigot end.

We also manufacture
G—K SEWER JOINT COMPOUND

the Original Bituminous Jointing Compound
for Vitrified Tile and Concrete Sewer Pipe

Amounts of G—K Compound required per joint, based on A. S. T. M. Terra Cotta Pipe dimensions.

Size of Pipe	Depth of Joint	Cubic Inches of Compound	Pounds of Jute	Pounds* G—K
4"	1¼"	8.2	.03	.52
6"	1¾"	19.2	.04	1.22
8"	1¾"	31.2	.15	1.98
10"	1¾"	38.1	.26	2.42
12"	1¾"	48.2	.31	3.07
15"	1¾"	55.	.40	3.5
18"	2¼"	83.7	.47	5.31
21"	2¼"	120.1	.65	7.59
24"	2¼"	136.5	.74	8.58
27"	2½"	202.2	1.29	12.87
30"	2½"	250	1.65	15.9
33"	3"	328	1.76	19.5
36"	3"	450	2.44	28.8

* This calculation is based on 10% excess for possible waste

THE DISTRIBUTION SYSTEM*

Some Basic Considerations in Its Design, Maintenance and Operation

By L. R. HOWSON
Consulting Engineer
Alvord, Burdick & Howson, Chicago, Ill.

IN ENDEAVORING to appraise the importance of the distribution system in water works practice, I first turned to the Journals of the American Water Works Association, an inspection of which disclosed that there were over twice as many papers relating to water quality and water treatment as there were with reference to the distribution system, including meters, unaccounted for water, hydrants and valves. Probably this is as it should be, for water quality is a matter of life and death; whereas proper design, operation and maintenance of a distribution system is primarily a question of economics. Undoubtedly this seeming lack of proper consideration for the economics of water supply results from the inability of the various program committees to secure constructive papers on what is generally considered a prosaic subject.

Economic Value of Distribution Systems

As a second step in appraising the economic importance of the water distribution system, the summaries of 16 recent water works appraisals were analyzed. The analyses showed that for these 16 plants the distribution system valuation averaged 66.8 per cent of the total plant value. While this percentage varied somewhat for individual plants, all but two fell within a range of 20 per cent of this numerical average. The weighted average of the percentage of the distribution value to the total plant value of the 16 plants was 65.3 per cent. It may be roughly stated, therefore, that two-thirds of the total value of the average water works is found in the distribution system. A check of valuations made as remote as thirty years ago shows this ratio to have remained practically constant.

The fact that two-thirds of the value of the ordinary water works is in the distribution system, and that 80 per cent of the distribution system value is in the item of mains and valves, indicates one of the most valuable yardsticks for an approximate indication of the value of a water works property of which there is no detailed inventory available. The length of pipe of the various sizes in the distribution system is always a matter of record and capable of easy conversion into tons. Normally the weight of pipe in a cast-iron distribution system will approximate 275 to 300 tons per thousand population.

Analysis of nine recent water works valuations, most of which involved transfer of ownership, revealed that the value of the entire system per ton of pipe in the distribution system was approximately $200. Cities with well supplies or without treatment will normally fall somewhat under the $200 per ton, and those with impounded supplies and costly purification works will be normally somewhat above the $200 per ton figure. The application of this figure, however, varied with respect to the facts relating to the source of supply in each particular case, will give a convenient and very approximate indication of the valuation of the entire water works property at the present time.

An analysis of these same nine water works valuations showed that the average per capita value as to the present time was $63. Since two-thirds of the value of a water works system is normally in the distribution system, it is apparent that the present-day distribution system in the average city has a value equivalent to about $40 per capita.

Some Basic Factors in Design

Too many distribution systems just grow. Very few distribution systems were scientifically designed originally and through growth, concentration and shifting demands need almost constant checking. The problem of designing an entirely new distribution system is seldom met in practice. The more frequent problem is that of designing a feeder or circulating system to correct deficiencies in capacity resulting from growth, reduction in carrying capacity, or allied causes. The National Board of Fire Underwriters, through periodic tests of distribution systems, has done much to uncover weaknesses and to indicate the requirements for reinforcement.

Every water distribution system supplies two distinct services; namely, the furnishing of normal domestic and industrial requirements and the water required to fight fires.

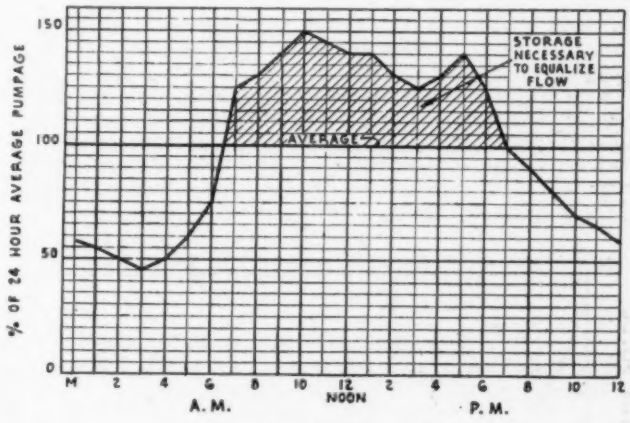
The former type of service extends more or less continuously over the entire area served. Fire demands are intermittent, concentrated in relatively small areas and of high intensity.

The domestic and industrial needs for water vary from day to day and from hour to hour. Ordinarily the maximum day of the year will be 50 per cent more or less in excess of the average day for the year, and on that maximum day, the peak hour will be 50 per cent more or less above the 24-hour average. Accordingly, the annual peak is approximately 2¼ times the average rate for the year. These percentages are subject to material variations for various cities but are sufficiently accurate for use in illustrating the comparative importance of ordinary and fire demands on the distribution system.

Elevated Tank Storage

The fact that the maximum rates prevail during but a portion of the day makes it possible to provide for them in whole or in part by storage in reservoirs or elevated tanks. Ordinarily, if elevated storage of from 20 to 40 gallons per capita (gpc.) is available, the rate of pumpage can be constant throughout the 24 hours of the day with all peaks met with water drawn from storage. It is, however, not necessary to provide storage in this amount to secure most of the benefits. Storage in the amount of but 25 per cent of the total storage requirement will ordinarily result in lowering the peak rate of pumpage by half its excess over the daily average. This 25 per cent storage provision is equivalent to only 5 to 10 gallons storage per capita.

Elevated tank storage sufficient to completely iron out hourly peaks is not very costly. Assuming 30 gpc. as the storage required in order that the supply and pumping equipment may operate at a uniform rate throughout the 24 hours of the day, the approximate present-day costs would be as follows:



Typical Hourly Pumpage Rates

Population	Elevated Tank Capacity	Elevated Tank Cost @ 12c/lb.	% Tank Cost to Value of Distr. System
5,000	150,000	18,000	9
25,000	750,000	69,000	6.9
50,000	1,500,000	132,000	6.6
100,000	3,000,000	250,000	6.25
200,000	6,000,000	500,000	6.25

The most of adequate elevated storage is thus from $2.50 to $3.60 per capita. Interest and depreciation at 6 per cent on this cost for municipal plants is but from 15 to 22 cents per capita per year, the equivalent of from 25 to 35 per cent of the average power cost where pumping is by electricity. Ability to avoid peak demand charges will frequently cover much of the fixed charges on the investment in elevated storage. The other benefits such as more uniform pressures, better operations of pumping

*A paper presented before the Wisconsin Section of A.W.W.A., the publication of which has been authorized by the Association.

equipment and safety against power outages, amply justify elevated storage in most water systems. The amount of elevated storage in each case is, of course, dictated by the individual conditions. The above is simply indicative of the possibilities to be developed.

Firefighting Considerations and Storage Costs

In addition to meeting all variations in domestic, commercial and industrial demands, a distribution system must be so designed as to transport the volume of water required for fighting fires. The rate at which water is required for fire service is a reflection of the character of development, whether suburban or metropolitan, fire hazards, and so forth. It varies approximately as the square root of population in thousands and is, therefore, proportionately greater for smaller communities. The following table gives the amount of water required by the National Board of Fire Underwriters for fighting fires in cities of various sizes:

Population	Fire Demand (GPM)
5,000	2,250
25,000	4,750
50,000	6,500
100,000	9,000
200,000	12,000

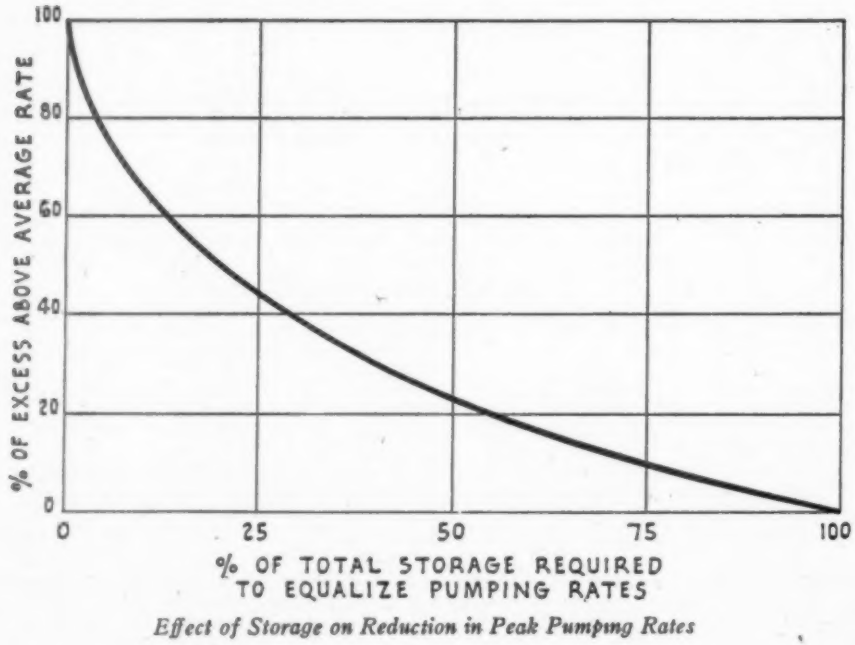
The above quantities are required in addition to the ordinary uses at the time, usually considered as 150 per cent of the average for the 24 hours.

Fortunately, fires do not occur at frequent intervals but they do occur with sufficient frequency and intensity to demonstrate the wisdom of making adequate provision for them. The extinguishment of fires ordinarily uses less than one-half of 1 per cent of the total pumpage.

The fact that fires are relatively of short duration indicates the possibility of storage to provide the water required for fighting fires, thus avoiding sudden extreme drafts upon water production systems. The following table shows the fire demand rate, the volume of water required during 10 hours at the several rates (Underwriter's requirement), and the estimated cost of reinforced concrete reservoir construction to store the fire requirements for cities of various populations:

Population	10 Hour Fire Use (Gallons)	Cost of Reinforced Concrete Reservoir*	Ratio of Reservoir Cost to Distribution System Value
5,000	1,350,000	$ 55,000	27.5%
25,000	2,750,000	93,000	9.3%
50,000	3,900,000	113,000	5.65%
100,000	5,400,000	135,000	3.37%
200,000	7,200,000	158,000	1.97%

*To store fire requirement—such costs being based on E.N.R. Construction Cost Index = 250.



Effect of Storage on Reduction in Peak Pumping Rates

If the topography is such that reservoir storage equal to the fire use can be so located as to float on the distribution system, it will relieve the source of supply, pumping equipment and distribution system of the fire demand and thus affect the total valuation of $63 per capita. It is also available and useful for domestic peaks at all times without cost other than interest and depreciation on the investment.

If the reservoir is built at ground level comparable to the station, but at a point near the opposite end of the distribution system from the pumping station, it is of value to the source of supply and the mains but duplicate pumping equipment will be required. A reservoir of this kind benefits about 90 per cent of the plant valuation when used during fire, but is of less value during other periods as booster pumps must be operated to make its benefits available.

If the water required to fight fires is stored in a low service reservoir or clear well at the pumping station, its effect is limited to the source of supply; i.e., usually less than 25 per cent of the property valuation.

An elevated tank to store the quantity of water required for fire in a 5,000 town would cost about $115,000. Since such a figure represents about 60 per cent of the value of the entire distribution system, it is evident that the primary justification for the elevated tank in the smaller systems is in equalizing hourly variations in domestic use.

The ratio of the water required for fire protection, and for peak domestic uses, is shown as follows:

Population	Peak Domestic Rate @ 225% of 100 gpc/day	150% Domestic plus Fire	Ratio Fire to Domestic Peak
5,000	1,125,000	4,250,000	3.7
25,000	5,625,000	10,600,000	1.88
50,000	11,250,000	17,000,000	1.51
100,000	22,500,000	27,900,000	1.24
200,000	45,000,000	47,300,000	1.05

It will be noted that for a city of 5,000, the peak demand during fire, which is based upon the fire use plus 150 per cent of the average day domestic, is 3.7 times as great as the peak hour domestic use; decreasing progressively to 1.88 for 25,000 population, 1.51 for 50,000, 1.24 for 100,000, and 1.05 for 200,000. In other words, for a city of approximately 200,000 population or larger, the peak domestic use rather than the fire requirement determines the size of the distribution system. For all populations less than 20,000 the fire requirement is the governing factor in the design of the distribution system.

Sizes of Mains

A water works distribution system consists of feeder mains and lateral distributors to serve consumers. The proportion of the total flow during fire which is carried through the laterals may vary from a negligible amount where the lateral system consists of 4-in. mains or smaller to a material proportion where the lateral distributors are 6-in. or larger. In order to ascertain how the pipe sizes vary in the average distribution system, the pipe systems of eight cities varying in population from 5,000 to 300,000 were studied. In the average of these systems, approximately 55 per cent of the mileage of mains was 6-in. in diameter with 15 per cent 4-in., another 15 per cent 8-in., and about half of the remainder 12-in. The weighted average size obtained by multiplying the footage of each size by its diameter and dividing the sum of the totals by the lineal feet, is approximately 7-in. This weighted average diameter varied but little between the eight systems, the maximum variation being not more than 5 per cent either way.

A few cities such as Des Moines, Iowa, have in recent years adopted 8-in. as the minimum size to use, in which case the proportion and capacities of feeder mains is less and the weighted average size of the mains larger. However, in very few cities does the weighted average size of mains materially exceed 7-in.

Larger diameters of pipe provide more carrying capacity per dollar expended, as is shown by the following table:

Diam. of pipe	Comparative Carrying Capacity*	Cost per foot Installed	Relation of cost to Capacity
4"	100	$1.10	1.1
6"	292	1.50	.52
8"	620	1.95	.31
12"	1,800	3.10	.17
16"	3,850	4.60	.12
20"	6,950	6.35	.09

*Based upon C = 120 of Hazen-Williams formula and pressure drop of 8 ft. per 1,000 ft.

The above estimates of cost are based upon Class B pipe at $50 per ton and costs of laying, which were the average of those used in six recent mid-western appraisals.

From an analysis of the above, it is apparent that a 6-in. main costs about 36 per cent more than a 4-in., but with the same friction loss will deliver 192 per cent more water. Correspondingly, an 8-in., which costs 30 per cent more than 6-in., will deliver 112 per cent more water, and a 12-in., which costs 59 per cent more than an 8-in., will deliver 191 per cent more water. Expressed in another way, increasing the pipe diameter by one size increases the carrying capacity from three to four times as much as the proportionate increase in cost.

Effect of Elevated Storage on Expenditures for Feeder Main

As a general line of demarcation it may be assumed that, in the ordinary distribution system mains, 6-in. in diameter and smaller primarily serve the normal domestic requirements; and that mains 8-in. and larger, in addition to serving these requirements, have been so designed as to provide a circulatory or feeder system to carry the water from the pumping station or reservoirs to the smaller distributing mains. The beneficial effects of elevated storage are, therefore, primarily limited to mains 8-in. and larger.

As stated, approximately 70 per cent of the footage of mains in the average distribution system is 6-in. or less in diameter. However, the mains of larger diameter cost more per foot, and an analysis of a considerable number of distribution systems shows that approximately 45 per cent of the value of the distribution system is in mains 8-in. and larger.

The value of the mains over 8-in. in diameter in the average distribution system is approximately $15 per capita.

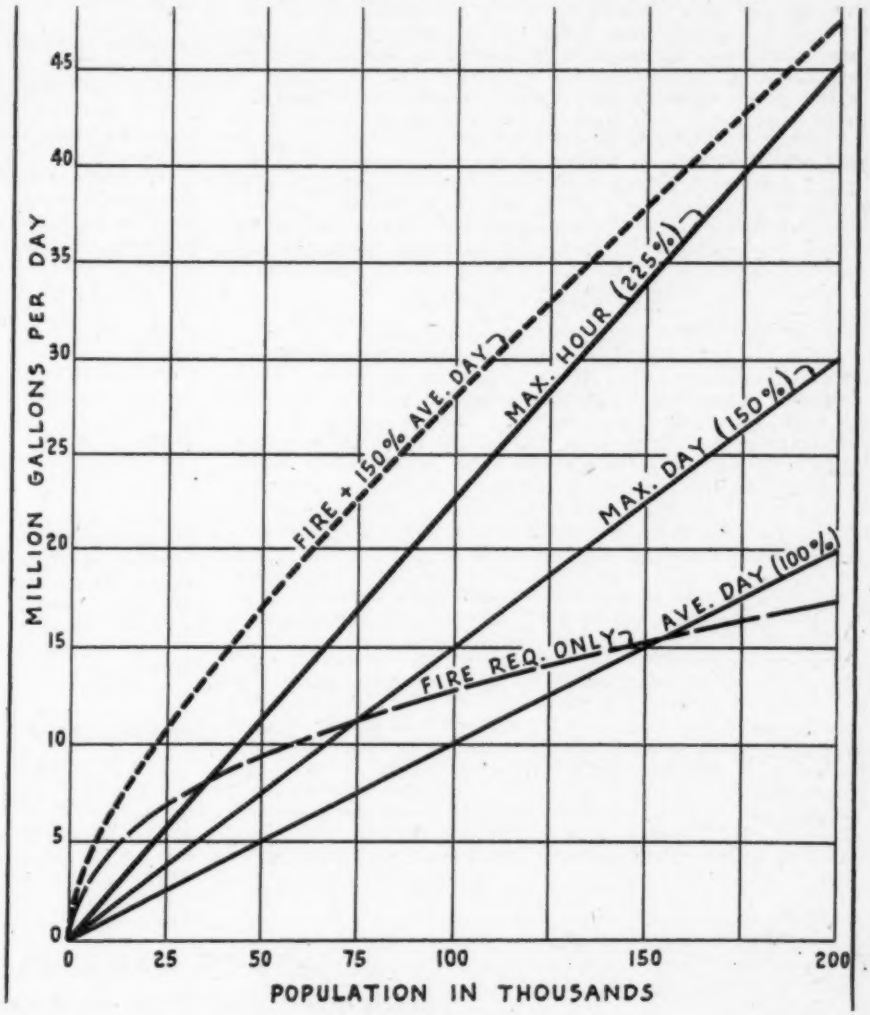
This value may be developed from the above figures on (1) the value of the average entire water works system at the present time, (2) the proportion of that value which is in the distribution system, (3) the proportion of the distribution system which is accounted for by mains, and (4) the percentage of total main value in mains larger than 8-in. In a city of 25,000 people the value of mains 8-in. and larger might be expected to be approximately $375,000.

Elevated storage sufficient to iron out the daily variations in flow in the average city of 25,000 population would cost approximately $69,000 at the present time, the equivalent of 18 per cent of the investment in feeder mains 8-in. and larger. If the topography is such that this peak requirement could be stored in a concrete reservoir at sufficient elevation, and not too distant, it would cost $36,000. This is less than 10 per cent of the investment in feeder mains.

There is obviously no general rule that can be laid down as applicable to all cities. In a recent study for a city where topography is such that strategically located reservoir storage could be provided within the area served by the distribution system, the provision of storage sufficient to provide for both domestic peaks and fire requirements cost approximately 30 per cent of the investment in feeder mains, and less than the expenditures required without storage for the proper reinforcement of the feeder main system.

Loss in Carrying Capacity

Another factor which has had a large effect on distribution system design has been the necessity of anticipating a loss in carrying capacity with the passage of time. The extent of this loss was evaluated by Edgar K. Wilson (Jour. AWWA, Vol. 28, No. 9), who showed that for midwestern waters in general, the Hazen-Williams coefficient decreased from 130 when new to 100 in about 20 years; a loss averaging more than one per cent per year. If such loss in carrying capacity were reflected in a comparable loss in valuation, this would be equivalent to a per capita loss of approximately $10 in a 20-year period, or 50 cents per capita per year, or nearly 10 per cent of the gross revenues of the average water utility.



Water Demand Rates
Domestic, Fire and Combined Fire and Domestic

Fortunately, this loss in carrying capacity is not correspondingly reflected in value. It is practicable to restore the carrying capacity to substantially its initial value by cleaning. Taking the average distribution system, the cost of such cleaning is approximately 5 per cent of the cost of the pipe installed new. Cleaning an entire system is seldom, if ever, resorted to. When main cleaning is done, it is usually confined to the feeder and circulating pipes where relation of cleaning to installation cost is even less than 5 per cent.

Loss of capacity, however, is a serious indictment of the water works industry. Certainly some method of protecting so large a proportion of the total water works investment should be available at reasonable cost. It is rather surprising that the heavier cement linings have not been more largely adopted. The cost of heavy cement lining varies from 6½ cents per ft. for 6-in. pipe to 26 cents per ft. for 20-in. pipe, equivalent to approximately 5 per cent of the cost of the pipe installed. If its use will maintain the carrying capacity of pipe (as seems probable

in most cases) its cost is well justified. Many designers have figured pipe sizes using Hazen-Williams coefficient of 100 instead of 130, in anticipation of loss in capacity. The cost of this excess capacity exceeds that of cement lining. Cement lining costs about the same as one cleaning but is better because it maintains capacity, whereas cleaning only periodically restores it. However, it is now possible to cement line mains in place after the cleaning operation.

Data regarding the maintenance of the coefficient of carrying capacity of cement-lined pipe are not so plentiful as for tar-coated pipe. The Cast Iron Pipe Research Association endeavored to secure such data by testing 42 cement-lined cast-iron pipe lines in 12 cities, located principally in the active or tuberculating water areas. All but eight of these mains had been in service from 10 to 16 years. The Hazen-Williams coefficient varied from 131 to 153, indicating little if any loss in coefficient value. Had these mains been tar-coated, it is believed the coefficient would have approximated 110.

The failure to adopt this improved coating more generally would appear to result from the average water works man's opinion that cast-iron mains, with the usual tar coatings, can be used in hard water areas without deterioration in carrying capacity. It is believed, by and large, that is not the case. It is suggested that, prior to the beginning of any important expansion of a distribution system, comprehensive flow tests be run and the relation between years of service and the Hazen-Williams coefficient be determined. If the loss is at all material, consideration of cement lining is suggested.

Unaccounted-for Water

There has been a greatly increased interest in "unaccounted for water" in recent years. As recent as 15 years ago, the average completely metered, well administered water works accounted for less than 75 per cent of the water used. At the present time that percentage is about 85 per cent, with a very few cities exceeding 90 per cent. One city of approximately 150,000 people, which had been completely metered for 40 years, was accounting for but slightly more than 60 per cent of the water pumped. By careful attention to its meters, their repair and accuracy of registration at low flows particularly, the accounted for water in this system has now been brought up to 83 per cent. The utility is now being paid for 35 per cent more water than before the improved meter maintenance program was started. The principal change was to see that all meters would register the low flows.

It is believed that the most important factor in reducing the quantity of water unaccounted for is the careful maintenance and repair of meters, with particular emphasis placed upon the accuracy of registration at low flows. Instead of referring to 15 to 25 per cent unaccounted for water, it has been suggested by Mr. A. P. Kuranz, Supt. of Water at Waukesha, Wis., that the unaccounted for water be visualized in terms of the equivalent waste of two to three months' coal, power and chemicals each year. In Mr. Kuranz's plant he has reduced the unaccounted for water to less than 7 per cent, an illustration of what can be done.

Water waste control, however, requires more than attention to the meters. It includes the necessity of locating leaks promptly and repairing them immediately. Every facility must be used to locate the hidden leaks, such as watching for melted spots on the streets during periods of light snow and listening at meters, valves and hydrants when routine inspections are being made.

Hydrants

Hydrants should be inspected at least twice each year, at which times they should be operated and checked for the operation of the drip, free draining, condition of packing etc. They should also be carefully inspected after each use in the cold weather months. Each hydrant, too, should have a card on which should be recorded everything done to the hydrant, including each semi-annual inspection and what was observed at that time. Such a record is invaluable in case attempt is made to fix liability for a non-operative hydrant which may result from an attempt to open in the wrong direction, mishandling or some other cause.

It is good practice to install hydrants farther back from the curb and street corners than was formerly the practice before the use of the automobile became so universal. It is also good practice to have a shut-off gate valve on every hydrant connection.

Hydrants should never be operated by other than the fire department or water works employees. The occasional use of fire hydrants to fill sprinkling wagons, and to flush sewers and streets, is bad practice. It jeopardizes the ability of the water system to function when most needed. In one city, where hydrant wrenches were too freely distributed, the annual cost of maintenance and repair was over $8 per hydrant as compared to an average of less than $3. The number of hydrants replaced, in proportion to those in use, was double that of other cities where the use of hydrants was properly restricted.

Valves

Valves should be inspected at regular intervals. If all valves do not open in the same direction, all exceptions should be recorded and their existence emphasized. Every valve should have a number and a card on which pertinent data relative to its location, installation, repair and maintenance are included. All valves should be provided with means of access, and it is good practice to install valves 12-in. and larger in vaults. Packing of valves should be inspected and adjusted when necessary.

Valves should be spaced at intervals of 500 to 800 ft. and so placed that no break will take more than two blocks of pipe out of service.

Distribution Maps

Too many water works either have no adequate map records or they are not kept up to date. A wall map should be available, of such scale as to make it usable. There should also be a sectional atlas of the entire pipe system on sheets about 24x36 in. and scale of 50 ft. or 100 ft. to the inch, with intersections and other congested areas enlarged when necessary.

WEIGHTS OF MATERIALS

Pounds per Cubic Foot — Average

BRICK	
Common Red	100
Silica	105
CEMENT	
Portland	94
Hydraulic	60
COAL AND COKE	
Anthracite	53 to 57
Bituminous	49
Charcoal	18
Coke	26
CONCRETE	
Cement, fine	137
Rubble, coarse	119
EARTH	
Loam, dry, loose	76
Loam, packed	95
Loam, soft, loose mud	108
Loam, dense mud	125
LIME	
Quick, loose lumps	53
Quick, fine	73
LIME STONE	
Large blocks	168
Irregular lumps	96
MASONRY	
Granite or limestone	165
Mortar, rubble	154
Dry	138
Sandstone, dressed	144
METALS	
Aluminum	166
Brass, cast	524
Bronze	534
Copper, cast	537
Copper, rolled or wire	555
Iron, cast	450
Iron, wrought	482
Lead, cast	708
Lead, rolled	711
Steel, cast	490
Steel, rolled	495
Tin, cast	459
Zinc, cast	438
OILS	
Engine	55
Crude	48
Petroleum	55
Gasoline	43
SAND	
Dry and loose	100
Dry and packed	110
Wet and packed	130
Gravel, packed	118
Gravel, bank	111
Gravel, dry	74
WATER	
Water, as ice	59
Water, at 32° F.	62
Water, at 212° F.	60

JOHNS-MANVILLE

Executive Offices: 22 E. 40th Street, New York 16, N. Y.

Offices in all large Cities

●

TRANSITE PRESSURE PIPE — TRANSITE SEWER PIPE

TRANSITE PRESSURE PIPE . . . *a brief discussion of how this asbestos-cement pipe can help you provide more efficient water service at lower cost—*

A SUMMARY OF TRANSITE PIPE'S OUTSTANDING CHARACTERISTICS

●

MADE OF ASBESTOS AND CEMENT — Transite Pipe is built up under tremendous pressure on a polished steel mandrel to form a homogeneous structure of great strength and uniformity.

RESISTANT TO VIBRATION—By virtue of its flexible joints, Transite Pipe is resistant to the shock and vibration of traffic; authoritative reports from abroad indicate the ability of flexibly connected asbestos-cement pipe to withstand indirect bomb shock with little or no effect on the performance of the line. Simplex Couplings divide the line into a series of flexible links which relieve the line of high flexural stresses and which have been found to localize damage in the case of direct hits.

HIGH CARRYING CAPACITY — Because of its smooth interior, Transite Pipe provides an unusually high flow coefficient, C=140.

CANNOT TUBERCULATE — Because it is nonmetallic, Transite Pipe can never rust or tuberculate. As a result, delivery capacity can never be reduced by this internal corrosion — expensive cleaning to remove tubercules is never required.

HIGHLY RESISTANT TO CORROSION — One of the important advantages of Transite's asbestos-cement composition and unusually low free-lime content is high resistance to corrosion — inside, outside and all the way through. Thousands of installations attest to Transite's durability in all kinds of soils.

TIGHT FLEXIBLE JOINTS—Composed of a Transite sleeve and two rubber rings, the Simplex Couplings used in Transite lines provide unusually tight, yet flexible joints.

WORKING PRESSURES—Transite Pipe is made in pressure classes of 50, 100, 150 and 200 for normal working pressures of 50, 100, 150 and 200 lbs. per sq. in.

EACH LENGTH RIGIDLY TESTED—Every length of Transite Pipe is individually tested to four times its specified rating in a hydrostatic test machine. In those sizes where flexural strength is important, each length of pipe is also subjected to a beam test.

SIZES—Transite Pipe is made in a wide range of sizes from 3-inch to 36-inch.

EASILY INSTALLED — Transite Pipe is furnished in long, 13-ft. lengths. Relatively light in weight, they are easily handled and installed. Simplex Couplings are assembled quickly and easily, even in wet trenches — a simple hydraulic coupling puller is the only tool required.

IN SELECTING a water pipe — whether for an extension or replacement of existing lines or the installation of a complete new system—careful consideration should be given to the basic factors contributing to the economic life of the pipe. For example:

DELIVERY CAPACITY . . .

Waterworks engineers generally agree that a water main, even though it remain structurally intact, may completely outlive its economic usefulness over a period of time. This point is reached when the pipe will no longer carry, economically, a sufficient volume of water to meet demand. Such a condition may arise from characteristics inherent in the pipe itself, from increased demand or from a combination of these two causes. Thus, in designing water systems, the engineer is faced with the responsibility of anticipating and solving these problems.

To compensate for expected reductions in carrying capacity, specifications often call for larger sizes of pipe than would otherwise be necessary. However, there is another, more fundamentally sound solution. In J-M Tran-

One of the hundreds of American Municipalities, where Transite Pipe is providing unusually efficient, economical water service. Transite's speed of assembly reduces the time trenches must be open—minimizes traffic congestion and inconvenience to business.

JOHNS-MANVILLE

Because it is immune to tuberculation, wherever used, Transite Pipe assures an abundant supply of water through the years with low pumping costs.

Over 62,000 feet of 10-inch to 30-inch Transite Pipe were used on this water collection and transmission system. Because of its light weight and speed of assembly, the pipe was laid as fast as the trench was opened.

site Pipe, engineers find basic advantages that permit them to specify the most economical pipe sizes with full assurance that delivery capacity will not be reduced by tuberculation, the internal corrosion which, even when present in relatively small degree, greatly reduces the carrying capacity of ordinary pipe.

Transite Pipe is an asbestos-cement product. During manufacture, it is built up on a polished steel mandrel that imparts unusual smoothness to the interior wall. Its flow coefficient is conservatively established at C = 140. This means that Transite water lines start with an exceptionally high carrying capacity.

Transite's freedom from tuberculation means that pumping costs stay low, for pressures need not be increased to compensate for a steadily decreasing flow coefficient and resulting loss of head in the line. Not only does this advantage provide worthwhile operating economies, but in many cases it also permits the use of smaller diameter pipe with resultant savings in all the numerous items that go to make up the original cost of completed water lines.

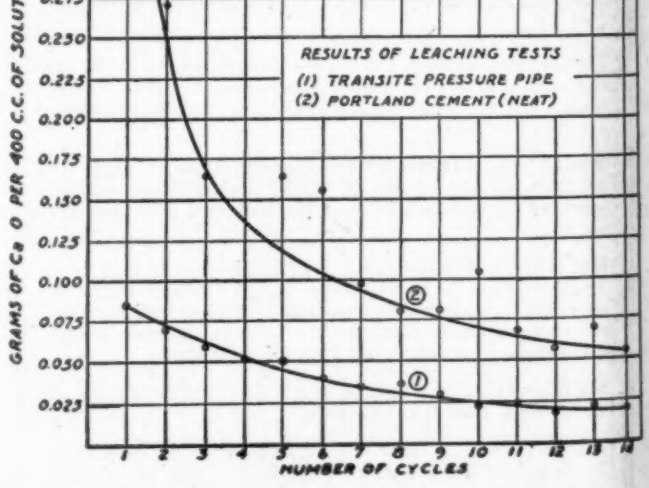
SOIL CORROSION . . .

Broadly speaking, most soil corrosion engineers agree that there are two principal forms of soil corrosion — chemical and electrochemical.

Chemical corrosion is caused by the direct, corrosive action of acids and salts encountered in the soil. Transite Pipe, due to a special process of manufacture and treatment, is virtually inert to concentration of acids and salts ordinarily found in soils. Free lime which might generally be expected in cement products, has been largely converted to insoluble silicates due to the method of manufacture. A comparison of the two curves in the diagram below shows the high degree of insolubility of Johns-Manville Transite Pipe. It is for this reason that Transite is so highly resistant to all forms of chemical corrosion.

Electro-chemical corrosion is caused by the electrolytic action between ordinary pipe and materials in the soil. This action is similar to that of a simple electric cell. In this case, the materials in the soil represent the positive pole; the soil moisture, the electrolyte, and the pipe wall serves as the negative pole. The current generated passes from the pipe to the positive pole and causes a gradual disintegration of the pipe structure.

With Transite, however, this condition can never



The chart above represents a series of leaching cycles for both pulverized Transite Pipe and neat cement. The small amount of free lime extracted from Transite indicates that for all practical purposes it may be considered insoluble—one of the major factors responsible for its unusual resistance to soil corrosion.

JOHNS-MANVILLE

occur, because being non-metallic, Transite is a non-conductor—therefore absolutely free from electrical corrosion. Furthermore, this asbestos-cement pipe is immune to electrolysis caused by stray electric current from high voltage lines, streets, railways, etc.

The successful performance of Transite Pipe in all kinds of soil and under many varying climatic conditions provides practical proof of its high resistance to corrosion—inside, outside and all the way through.

JOINT LEAKAGE . . .

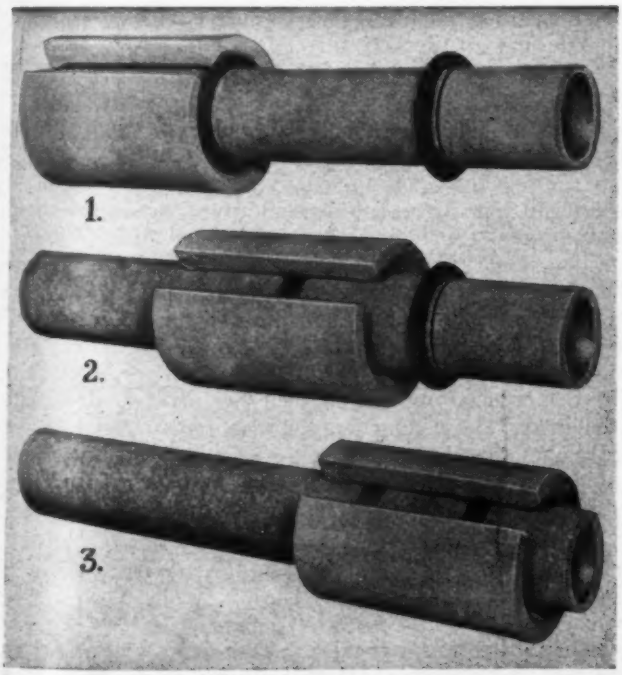
Numerous surveys have shown that leaky joints are responsible for a considerable portion of total water losses from underground mains. Generally recognized by waterworks men as a serious problem, joint leakage not only results in a direct waste of water but, by washing away supporting soil, frequently causes pipe to fracture under traffic and earth loads.

Much of this trouble is caused by the fact that the ordinary rigid joint, even though perfectly made by skilled workmen, may open up when subjected to vibration or settlement after the line is in service.

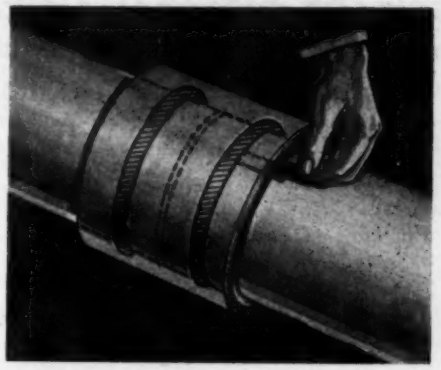
Such potential losses are minimized with a flexible joint. And that is the principle upon which the Simplex Coupling, employed in assembling Transite Pipe, was designed. Consisting of a Transite sleeve and two rubber rings, it forms a tight joint that stays tight in service. Its flexibility compensates for vibration and for vertical, longitudinal and lateral movements to which the pipe may be subjected underground. Depending upon the size of the pipe, a deflection of as much as 5° is possible at each joint.

From a practical standpoint, the less skill required in assembly, the less the danger of defective joints in the field. The dependability of the Simplex Coupling is due primarily to these distinctive features:

1. It is actually a pre-fabricated, "packaged" joint. The ends of each pipe and the inside of each coupling



Simplex Couplings Assembly (1) at start of operation (2) sleeve pulled over one ring, (3) final position, sleeve centered over joint.



With Simplex Couplings tightness of the joint can be determined from the outside as soon as the pipe is laid. A thin steel blade, slipped under the lip of the sleeve, checks the position of the rubber ring. If the position is right, the joint is tight.

are machined to specific dimensions. The rubber rings are precision-made and subjected to rigid inspection before shipment. Joints are assembled cold—no pouring, caulking or heating equipment is needed. A simple hydraulic coupling puller, loaned by Johns-Manville without charge, is the only tool required for assembly.

2. The effectiveness of the joint does not depend on the individual skill or training of the workmen. So simple is the operation that perfect Simplex joints can be made quickly and economically even by unskilled crews.

Made of Permanent Materials. The Transite sleeve, like the pipe itself, is made of asbestos and cement and has the same high degree of resistance to all forms of corrosion. The rings, made of the highest quality rubber, are carefully cured and specially compounded with anti-oxidents and properly graded non-hygroscopic fillers to assure permanence in water service.

INSTALLATION . . .

One of the major factors contributing to initial cost of a pipe line is the time and equipment required for installation.

Transite Pressure Pipe offers primary advantages that help speed up installation and cut costs. The long, 13-ft. lengths are relatively light in weight. Two or three men can easily lower 8 inch pipe into the trench by hand. In fact all but the very largest sizes can be handled without the use of mechanical equipment.

Simplex Couplings are assembled cold just as they are received from the factory. Wet trenches present no problem for no heating or caulking equipment is required. And the complete assembly is completed in much less time than required by ordinary types of joints.

WRITE FOR COMPLETE DETAILS

A detailed discussion of the economic factors contributing to efficient, low-cost water lines is given in the Transite Pressure Pipe Brochure, TR-11A. The 76-page "J-M Pipe Installation Manual," D. S. 332, outlines effective methods of installing water lines and includes much more data on Transite Pipe and the Simplex Coupling than was possible to include on these pages. For detailed data on making repairs to transite lines damaged by enemy action the booklet, "Transite Pipe—Repair of War Damage" will be found helpful. It is profusely illustrated and contains numerous diagrams and data pertinent to the maintenance of flow in the event of hostilities. For your free copy of these three books, write to Johns-Manville, 22 East 40th Street, New York 16, N. Y.

JOHNS-MANVILLE

IN YOUR SEWAGE DISPOSAL SYSTEMS - - -

Transite Sewer Pipe offers fundamental advantages that help reduce the cost of sewer line construction, maintenance and operation.

TRANSITE PRESSURE SEWER PIPE

Pressure Sewer Lines are very similar in operation to water lines and must meet the same general service requirements. In addition, the pipe must be highly resistant to the corrosive action of the sewage. Transite Pressure Sewer Pipe, which is made of the same durable asbestos-cement composition as Transite Water Pipe, described on the preceding pages, meets all these requirements and provides highly satisfactory service in systems of this type.

TRANSITE GRAVITY SEWER PIPE

Gravity Sewer Lines offer a number of specialized problems which Transite Gravity Sewer Pipe meets eminently well. For example:

INFILTRATION—

It has been authoritatively estimated that as much as 25% of the contents of the average sewer is ordinary ground water that enters the system by infiltration through the joints. And it costs practically as much to treat this water at the disposal plant as it does to treat sewage itself. Furthermore, in many cases, engineers must allow for this huge quantity of water by specifying a larger diameter pipe than would otherwise be necessary.

With Transite Sewer Pipe, however, the infiltration of ground water presents no serious problem. Transite's long 13-ft. lengths cut down the number of joints in the line, thus reducing the danger of infiltration right at the start. The poured sleeve joints employed in Transite lines are unusually tight and stay tight in service. The jointing compound is the highest quality, unfilled asphalt which, when set, provides a strong, flexible joint that is highly resistant to cracking or shrinkage. As a result, Transite Sewer Pipe lines have considerably less infiltration than that allowed by most specifications.

Transite, the corrosion-resistant, asbestos-cement sewer pipe, answers every requirement of efficient sewerage service. Its long 13-ft. lengths make laying to exact grades a quicker and more accurate job. And the tight joints employed minimize infiltration.

CARRYING CAPACITY

One of the most important factors in any sewer line is carrying capacity. All other things being equal, the relative carrying capacity of two or more types of pipe is best indicated by their flow coefficient. If, for example, the inside of the pipe is rough and uneven, the flow velocity is low and carrying capacity is greatly reduced. A smooth pipe, however, has a high flow velocity and a correspondingly high carrying capacity.

Transite Sewer Pipe has an unusually smooth interior surface, its conservative friction coefficient when installed at the usual sewer pipe grade is N=.010. This high carrying capacity results in savings that can be taken in one of two ways. Flatter grades may be employed during installation — reducing the depth of the trench and making installation a faster, more economical job. Or, when the usual sewer pipe grade is maintained and deep trenches present no problem, Transite's high flow velocity often makes it possible to use a smaller diameter pipe without reducing the desired carrying capacity of the system.

OTHER CONSIDERATIONS

Resistance to corrosion, structural strength and ease of installation are, of course, other important considerations in the selection of sewer pipe.

Because of its asbestos-cement composition and its unusually low free lime content, Transite Sewer Pipe is highly resistant to the corrosive action of all types of domestic sewage and most industrial wastes—inside, outside and all the way through.

Transite Sewer Pipe is furnished in sizes from 4" to 36" in Class I, from 10" to 36" in Classes II and III and from 18" to 36" in Class IV. Each class of pipe is made to a specific crushing strength, thereby providing for the selection of the most economical combination of classes of pipe to meet the specific strength requirements of the line.

The long 13-ft. sections in which Transite is furnished eliminates many of the difficulties in installation common to ordinary short length sewer pipe. Relatively light in weight, these long lengths cut down handling costs. More footage may be carried per truck load to the trench and fewer men are needed to install the pipe. These long lengths also reduce the number of joints that must be made and thus save considerable time and labor. In addition, long lengths greatly facilitate laying the pipe to an accurate grade.

It will pay you to get further details about this modern sewer pipe. Brochure TR-21A presents them in brief, quickly read form. The "Transite Sewer Pipe Installation Manual" D.S. 342 gives valuable information and tabular data pertinent to installation problems. Write for these from Johns-Manville, 22 East 40th Street, New York 16, N. Y.

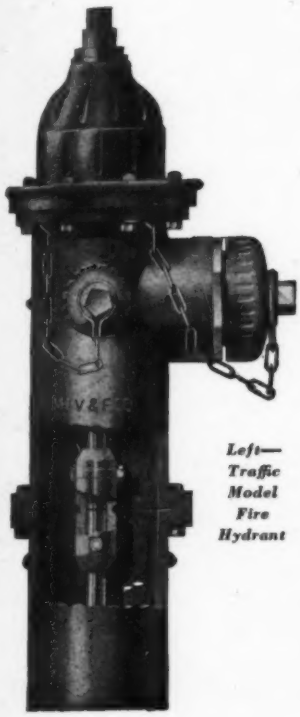
JOHNS-MANVILLE JM PRODUCTS

M & H VALVE AND FITTINGS COMPANY

ANNISTON, ALABAMA

VALVES, HYDRANTS AND WATER WORKS ACCESSORIES

Efficient domestic water systems, sanitary sewage systems, and fire protection for municipalities involves a great number of control valves and hydrants. M & H products with their record of high quality, rugged strength and dependability can safely be recommended.



Left— Traffic Model Fire Hydrant

M & H FIRE HYDRANTS

Conform to latest A.W.W.A. specifications. Simple, rugged design minimizes maintenance costs. Features are:

1. **Dry Top—Operating threads protected from action of water. No rust, corrosion or freezing.**
2. **Easy Lubrication of operating nut, threads and packing through lubricating screw in top of operating nut.**
3. **Revolving Head, outlets faced in any direction.**
4. **Addition of Steamer Nozzle, without digging up hydrant or requiring complete new barrel.**
5. **Lengthening of Hydrant without digging up or requiring complete new barrel.**
6. **Double Lead Gaskets on Bronze valve seat.**
7. **Removal of Bronze Seat, or any working part, without digging up Hydrant.**
8. **Double Drain Valves, absolutely positive, insuring quick and complete draining of Hydrant.**
9. **Lugs on Bell of Hydrant Shoe for strapping to the water main, if desired.**
10. **Compression Type. Water pressure keeps valve tight.**

SPECIAL TRAFFIC MODEL FIRE HYDRANT

Equipped with cast iron bolts and breakable coupling on the stem. Breakage due to traffic collision is limited to these cast iron parts which are easily and quickly replaced without shutting off the pressure.

M & H A.W.W.A. GATE VALVES

Iron body, bronze mounted gate valves are furnished in the double disc parallel seat or solid wedge types with non-rising stem, outside screw and yoke, or with sliding stem and lever. Supplied to fit any standardized pipe connections. By-pass valves can be furnished, unless otherwise specified, in sizes according to A.W.W.A. specifications.

SPECIAL TYPES

Hydraulically Operated: **for remote control of operation and for quicker, easier opening or closing. Can be supplied in any of the standard sizes of M & H A.W.W.A. gate valves, either high or low pressure.**

M & H Square Bottom Gate Valves: **specially designed for operation in any position. Particularly recommended for use in intake towers or at the foot of dams; for pressure regulation by throttling the flow of water in centrifugal pump discharge lines; for regulation of flow in feed line to a filter bed; and for flow regulation from a reservoir where there is unbalanced pressure against the gates.**

PRESSURE CLASSIFICATION—2″ TO 30″ SIZES

Class	Working Pressure	Hydrostatic Test
AA	0 - 25 lb.	50 lb.
A	26 - 50 lb.	100 lb.
B	51 - 100 lb.	200 lb.
C	101 - 200 lb.	350 lb.

CHECK VALVES

For intsallation in horizontal or vertical position. Can be supplied with by-passes. May be furnished with an outside lever and weight. Sizes from 2″ to 12″ for working pressure up to 200 lbs.

OTHER PRODUCTS

Tapping Valves
Mud Valves
Shear Gates
Flap Valves
Wall Castings
Floor Stands
Flanged Fittings
Flange and Flare Fittings
B & S Fittings
Cutting-In Tees
Valve Boxes
Special Castings

BINS, Storage
BREECHING, Steel
CHUTES, Steel
FILTRATION PLANTS
FLUMES, Iron and Steel
GAS HOLDERS
HOPPERS, Steel
PENSTOCKS
PIPE, Riveted steel
PIPE, Welded steel

CHICAGO BRIDGE

Chicago 4.....2198 McCormick Bldg.
New York 6.3390—165 Broadway Bldg.
Cleveland 15.....2262 Guildhall Bldg.
Greenville.....York Street
Birmingham 1.....1586 North 30th St.
Tulsa 3.....1646 Hunt Bldg.
Plants in CHICAGO, ILL.; BIRMINGHAM, ALA., and GREENVILLE, PA.

1,500,000-gal. radial-cone bottom tank at Indianapolis, Ind.

The Chicago Bridge & Iron Company has been designing, fabricating and erecting elevated tanks, storage tanks, pressure vessels and steel plate work for municipal service for over 50 years. We shall appreciate the opportunity of suggesting designs or submitting estimating figures to municipal officials or waterworks engineers who may be planning installations of this type. When estimates are desired on tanks—state capacity, height to bottom for elevated tanks and describe location. Address our nearest office.

RADIAL-CONE BOTTOM TANKS

The radial-cone bottom design was developed to enable us to build large capacity tanks with a small range in head. Radial-cone tanks are of sound structural design. They present a pleasing appearance. Construction details such as the columns, balcony, hand railing, etc., may be varied to secure the desired architectural effect. The accompanying table indicates the proportions for the various capacities.

Write for your copy of booklet showing photos of various sizes of radial-cone bottom tank installations . . . free upon request.

1,000,000-gal. tank at Tucson, Arizona

1,500,000-gal. unit at San Antonio, Texas

400,000-gal tank at Olney, Ill.

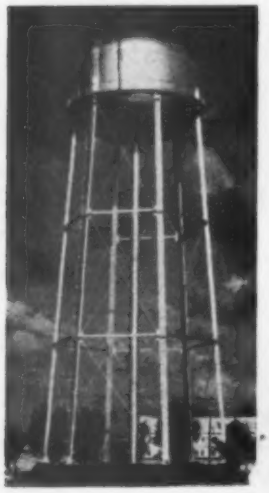
STANDARD RADIAL-CONE SIZES

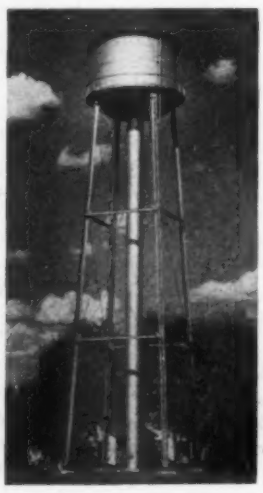
Capacity (Gallons)	Diameter of Tank	Depth of Tank
500,000	61'	25'
750,000	76' 8"	25'
1,000,000	87'	25'
1,500,000	106'	25'
2,000,000	122'	25'

A booklet is available, showing various steel radial-cone bottom tank installations.

ELLIPSOIDAL-BOTTOM ELEVATED TANKS

The elevated tanks shown below are typical ellipsoidal-bottom installations. To the left is a 200,000-gal. tank at Hollywood, Fla. The one in the center is a 500,000-gal. tank located at Bristol, Penna. The ellipsoidal-bottom tank with a cone roof shown at the right is a 40,000-gal. structure at Warrensburg, Ill.





Ellipsoidal-bottom elevated tanks are available in standard sizes as shown in the table below. The tank diameter is relatively large and the depth shallow. This reduces the variation in pressure between upper and lower water levels. Ellipsoidal-bottom tanks are available with two types of roofs: cone or ellipsoidal. The two tanks at the extreme left are typical installations with ellipsoidal roofs and bottoms. The other photo shows an ellipsoidal-bottom tank with a cone roof.

ELLIPSOIDAL-BOTTOM TANK SIZES

Nominal capacity, gal.	Tank dimensions			
	D	H	B	K
40,000	20'0"	13'9"	5'0"	18'9"
50,000	22'0"	14'0"	5'6"	19'6"
60,000	24'0"	14'0"	6'0"	20'0"
75,000	26'0"	15'0"	6'6"	21'6"
100,000	28'8"	16'0"	7'2"	23'2"
125,000	28'8"	21'2"	7'2"	28'4"
150,000	34'0"	16'6"	8'6"	25'0"
200,000	38'0"	17'6"	9'6"	27'0"
250,000	40'0"	20'0"	10'0"	30'0"
300,000	41'0"	23'0"	10'3"	34'0"
400,000	47'0"	23'2"	11'9"	34'11"
500,000	51'0"	24'3"	12'9"	37'0"
600,000	54'0"	26'3"	13'6"	39'0"
750,000	54'0"	32'0"	18'0"	50'0"
1,000,000	60'0"	34'0"	20'0"	54'0"
2,000,000	80'0"	35'6"	26'0"	61'6"

Height to bottom—any even foot.

& IRON COMPANY

Houston 1.....5615 Clinton Drive
Philadelphia 3..1644—1700 Walnut St.
Washington 5.....330 Bowen Bldg.
San Francisco 5.....1083 Rialto Bldg.
Havana.....402 Edificio Abreu

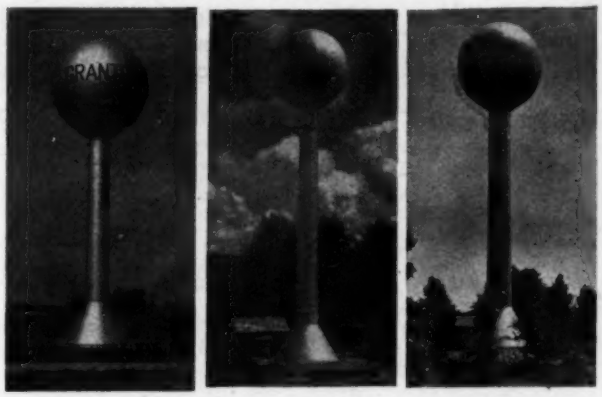
In Canada: HORTON STEEL WORKS, LIMITED, Fort Erie, Ontario

PRESSURE VESSELS, Welded
RESERVOIRS, Steel
RECEIVERS, Air
SMOKE STACKS
STANDPIPES

STEEL PLATE WORK
TANKS, Elevated Steel
TANKS, Storage
TANKS, Surge
TANKS, Washwater

THE WATERSPHERE

This relatively new elevated water tank design has attracted wide public interest because of its unusual shape. Engineers and water works operators have found that Waterspheres embody highly functional construction. A single cylindrical column provides an economical means of supporting an elevated tank. The plain plate surfaces are easier to maintain than built-up structural columns. Waterspheres have been installed in many municipalities, in sizes ranging from 40,000 to 250,000 gallons.

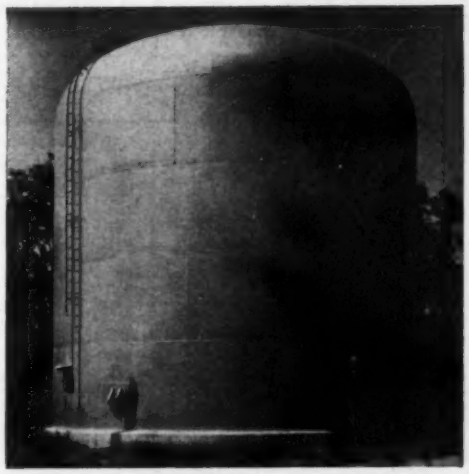


Three typical Watersphere installations are shown at the right. Capacities and locations are (left to right) 50,000-gal., Granton, Wisconsin; 75,000-gal., Watsonbury, N. C.; 150,000-gal., Kent, Ohio.

MISCELLANEOUS TANKS

WASHWATER TANKS

We build ellipsoidal, radial-cone or special shaped tanks to give the capacity, head and pressure variation required for washing filters. Shown at the left is a 100,000-gal. washwater tank at Michigan City, Ind.



FLAT-BOTTOM WATER STORAGE TANKS

Shown at the right is a 250,000-gal. ellipsoidal-roof, flat-bottom water storage tank at Kent, Ohio. We build tanks of this type in any diameter and height to meet your requirements.

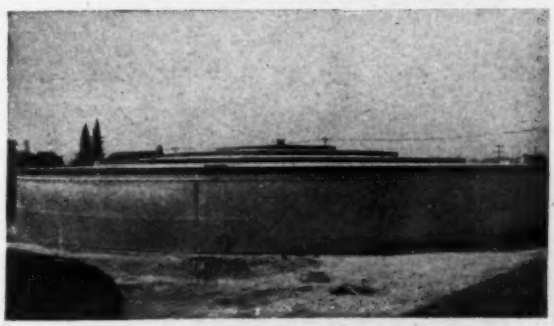
HORTONSPHERES
Sewage Gas Holders

Gas produced in digestion chambers at sewage disposal plants may be used to advantage for normal heating and power needs. When excess quantities of this gas is produced it may be stored advantageously under pressure in Hortonspheres for use during periods when gas production is low. The Hortonsphere at the left holds 25,000 cu. ft. of gas at the Boulevard sewage disposal plant in New Haven, Conn. The installation at the right is at Muncie, Ind. It is a 32-ft. diam. sphere and operates at 29.9 lbs. pressure.

We also build conventional lift-type gas holders.

RESERVOIRS

Where natural elevations are available, flat-bottom steel reservoirs provide efficient gravity pressure. They are built in standard sizes or special designs to meet your requirements, of riveted or welded construction, with or without roofs.



Right: One of two 2,300,000-gal. all-welded steel water reservoirs installed at Alhambra, Calif.

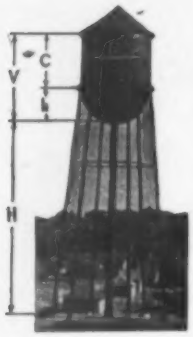
PITTSBURGH-DES MOINES STEEL CO.

Tanks—Plate Fabrication—Structural Steel

Sales Offices at: 3418 NEVILLE ISLAND, PITTSBURGH, PA. . . . 919 TUTTLE STREET, DES MOINES, IOWA
ROOM 918—270 BROADWAY, NEW YORK . . . 1222 FIRST NATIONAL BANK BLDG., CHICAGO, ILL.
1223 PRAETORIAN BLDG., DALLAS, TEX. . . . 625 RIALTO BLDG., SAN FRANCISCO, CALIF.

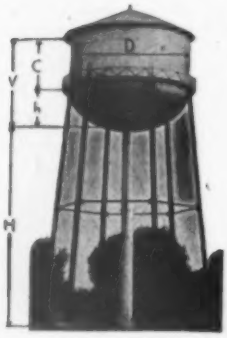
In these tables we have compiled—in compact but complete form—data on steel reservoirs and on the various types of elevated steel tanks. For information as to the application of these various types of tanks, for designs, for specifications, or for estimates—write our nearest office.

Table I—Pittsburgh-Des Moines Standard Hemispherical Bottom Elevated Tanks



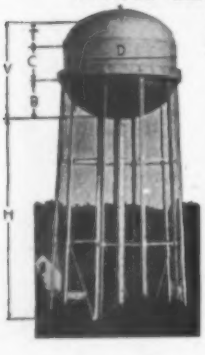
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
5,000	9	10 0	11 3	11 3	18 9	31 9	38 2	51 9	58 9	72 9	79 9	93 9	100 9	.....	.....	
10,000	13	5 11	11 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....	
15,000	13	10 11	16 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....	
20,000	13	15 11	21 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....	
25,000	15	14 7	19 11	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....	
30,000	15	18 5	23 9	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....	
40,000	17	18 5	25 1	46 8	.....	.....	75 0	.....	96 3	100 0	.....	125 0	.....	.....	.....	
50,000	19	17 7	25 7	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4	
60,000	19	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4	
75,000	21	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4	
100,000	24	22 6	31 9	.....	50 0	63 1	75 0	79 7	91 6	100 0	113 1	116 6	128 0	141 6	153 1	
150,000	24	34 2	34 7	46 6	54 10	63 2	75 0	83 4	91 8	100 0	111 10	120 2	128 6	140 2	148 7	
200,000	32	23 4	36 1	45 9	54 1	62 5	75 0	83 4	91 8	100 0	112 7	120 11	129 3	141 10	150 2	
250,000	32	31 4	45 4	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0	
300,000	36	28 4	42 5	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0	
400,000	40	30 0	46 6	44 6	52 10	61 2	75 0	83 4	91 8	100 0	113 10	122 2	130 6	128 10	160 2	
500,000	44	29 9	49 2	43 6	51 10	60 2	75 0	83 4	91 8	100 0	114 10	123 2	131 6	139 10	164 7	
600,000	44	38 6	58 2	Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.												
750,000	50	34 9	57 5													
1,000,000	50	52 0	73 9													

Table II—Pittsburgh-Des Moines Standard Hemi-ellipsoidal Bottom Elevated Tanks



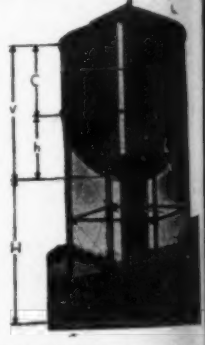
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
25,000	17	11 9	15 5	46 4	51 8	71 4	75 0	.....	96 4	100 0	.....	126 8	.....	.....	
30,000	17	14 7	18 6	46 1	51 5	71 1	75 0	.....	96 1	100 0	.....	126 5	.....	.....	
40,000	21	11 3	16 9	47 8	.....	.....	75 0	.....	97 5	100 0	.....	126 2	.....	.....	
50,000	22	13 2	19 0	.....	57 2	65 6	75 0	85 6	93 10	100 0	113 10	122 2	130 6	142 2	146 6
60,000	24	12 10	19 4	.....	56 6	64 10	75 0	84 8	93 2	100 0	113 2	121 6	129 10	141 6	149 10
75,000	26	13 6	20 8	.....	55 10	64 2	75 0	84 2	92 6	100 0	112 6	120 10	129 2	140 10	149 1
100,000	28	16 2	23 2	.....	51 6	64 7	75 0	81 1	93 0	100 0	114 7	118 0	126 6	143 0	154 10
150,000	34	14 10	25 0	46 9	55 1	63 5	75 0	83 7	91 11	100 0	112 1	120 5	128 9	140 6	149 10
200,000	38	15 5	27 0	46 11	55 3	63 7	75 0	84 6	92 0	100 0	113 9	122 1	130 5	143 0	151 4
250,000	40	18 1	30 0	47 5	55 9	64 1	75 0	85 5	93 9	100 0	115 1	123 5	131 9	140 1	153 5
300,000	40	23 11	34 0	49 4	57 8	66 0	75 0	87 4	95 8	100 0	117 0	125 4	133 8	142 0	156 0
400,000	46	22 9	34 11	48 10	57 2	65 6	75 0	87 8	96 0	100 0	118 2	126 6	134 10	143 2	157 2
500,000	50	23 9	37 0	49 8	58 0	66 4	75 0	81 2	89 6	100 0	112 8	121 1	129 4	146 0	160 8
600,000	55	21 9	39 7	Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	60	22 4	42 4												
1,000,000	60	35 0	54 0												
1,000,000	65	26 1	47 7												
1,250,000	79	17 4	43 4												
1,500,000	70	37 8	60 0												
1,500,000	79	24 0	50 0												
2,000,000	90' 3"	22 6	50 0												

Table III—Double Ellipsoidal Tanks



Capacity in U.S. Gallons		B	C	T	V	H
50,000	22'-0"	5'-10"	9'-4"	4'-4"	19'-6"	
75,000	26'-0"	7'-0"	9'-0"	5'-0"	21'-0"	
100,000	28'-0"	7'-0"	11'-1"	5'-7"	23'-8"	
150,000	36'-0"	10'-0"	8'-8"	6'-10"	25'-6"	
200,000	40'-0"	9'-0"	12'-11"	6'-9"	28'-8"	Built
250,000	40'-0"	10'-4"	11'-7"	7'-6"	29'-5"	
275,000	44'-0"	11'-11"	13'-9"	7'-6"	33'-2"	to
300,000	46'-0"	8'-7"	17'-11"	7'-6"	34'-0"	
350,000	50'-0"	14'-8"	13'-10"	8'-0"	36'-6"	Order
400,000	55'-0"	12'-2"	14'-9"	8'-8"	35'-7"	
500,000	60'-0"	15'-0"	14'-6"	9'-8"	39'-2"	
600,000		14'-4"	14'-0"	10'-0"	38'-4"	
750,000		15'-11"	12'-7"	11'-6"	40'-0"	
1,000,000	65'-0"	21'-8"	15'-9"	11'-0"	48'-5"	

Table IV—Railroad Type Tanks



Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft.	C in.	V ft.	V in.	H
20,000	15	10	9	16	2	
25,000	15	14	7	19	11	Any
30,000	17	12	7	19	0	height
40,000	19	13	1	20	6	from
50,000	21	13	1	21	1	15' 0"
60,000	24	10	1	20	3	to
75,000	24	15	1	23	10	40' 0"
100,000	28	13	5	23	7	in
150,000	28	14	2	24	7	multiples
200,000	36	15	1	29	2	of
250,000	38	17	3	33	3	5' 0"
300,000	38	23	11	38	3	

Table V—Toroidal Bottom Tanks

Capacity in U.S. Gallons	Tank Diameter (D) when h = 10' 0" and V = 20' 0" ft.	in.	V = 25' 0" ft.	in.	V = 30' 0" ft.	in.	V = 35' 0" ft.	in.	H
750,000	82	0	73	2	66	8	61	8	
1,000,000	94	5	84	3	76	9	71	0	
1,250,000	105	4	94	0	85	8	79	2	Built
1,500,000	115	2	102	9	93	9	86	8	to
2,000,000	132	8	118	5	108	0	99	11	Order
2,500,000	148	0	132	3	120	7	111	6	
3,000,000	162	0	144	8	131	11	122	1	
4,000,000	186	8	166	9	152	2	140	9	
5,000,000	208	6	186	3	169	11	157	3	

Table VI—Steel Reservoirs

Capacity in U.S. Gallons	Diameter ft.	Height ft.	in.
50,000	20	21	
60,000	22	21	
75,000	24	22	
100,000	26	25	
150,000	30	28	
200,000	34	29	
250,000	38	29	
300,000	42	29	
400,000	46	32	
500,000	50	34	
750,000	60	35	
1,000,000	70	35	
1,500,000	80	40	
2,000,000	95	38	
2,500,000	110	35	
3,000,000	120	35	
4,000,000	130	40	

ELEVATED STORAGE

The Value of Elevated Tanks on Water Supply Systems

By CHARLES BROSSMAN

Late Consulting Engineer, Indianapolis, Ind.*

In many cities the advantages of elevated water storage has been recognized, usually with considerable return on the investment.

On closed water systems without some form of storage facilities, where centrifugal pumps are in service, the pumps are usually installed large enough to take care of peak loads. It is quite evident that, with a pump available to take care of such peak loads, on the lighter loads (especially at night), the pump drops off greatly in efficiency, as does the motor. Such day in and day out waste of power mounts to an appreciable sum as time passes, until losses overbalance the costs of providing storage on the system —in instances many times over.

For instance: Assume a modern pump operating at full load efficiency of 70%, and motor at 90%. The unit will give a combined efficiency of 63%. This pump on the lighter loads, with a drop in efficiency of 50%, and the motor at 80%, gives a combined efficiency of only 40%, a difference between the two of 23 points.

It is readily realized that with such a condition recurring daily, the power consumption may be surprisingly increased for the year. Not alone such current waste, but if power is being purchased with a maximum demand charge on the motor size the rate will be increased due to this factor, for the reason that the pump motor must be large enough to take care of the peak load. On the other hand, an elevated tank will allow more uniform pumping, the pump and motor size can be reduced, thereby reducing the costly demand factor.

Another very evident disadvantage is that pressure is lost immediately whenever pump service is interrupted for any of several possible reasons. In case of fire such is disastrous. In any case, the public served is paying a penalty in insurance rates where pressure storage is not available on the system.

Furthermore, another advantage from elevated storage is that any pump on the line can be used at its maximum output, and with a correspondingly maximum efficiency. Pumps, therefore, can be purchased for use with elevated tank service over their maximum range of efficiency, with assurance that such efficiency can be realized in every day operation.

Another advantage is uniform pressure. With an elevated tank, automatic regulating control is available, whereby the tank variation in head may be kept within a few feet, thereby giving absolutely uniform pressures under all conditions of draft on the system. Particularly advantageous are elevated tanks in outlying districts, to reduce pumping costs and render better service pressures and flow. It is hardly necessary to indicate that more water will be used, in consequence, and a higher income enjoyed by the water utility.

In considering the values of elevated tanks for water storage it is apparent that there are a number of advantages.

Power Saving Case Records

The first advantage, that of saving in power cost, is the most appealing and in practically all cases a considerable saving in power will result. As a concrete example we may take the experience of a small plant in a town of 1,100 with which the writer is very familiar.

The Town of Albion, Indiana, had a water consumption of approximately 50,000 gallons per day. In this case an elevated tank was installed, the total cost of the tank being approximately $7,200.00. The power used before installing this tank, on the closed system, was approximately 1 KWH for 530 gallons; after the tank was installed, pumping was approximately 1 KWH for 1,050 gallons. This proved a spectacular attainment of cutting power consumption in half, but there are other Albions scattered over the country.

In this particular case, the tank will be paid for in less than 15 years by the saving in power bills alone. If the rate of consumption increases the time will be shorter, of course.

Here is a point of considerable interest in this case. Albion has its own generating plant, and the total cost of power is considered at 3c per KWH, including all costs. A careful check on all costs and power used still indicates the investment well justified. One reason is found in the fact that fire protection is now supplied with the small 200 G.P.M. pump and the large steam fire pump is no longer maintained as a ready to serve unit with fire in the boiler. Steam, however, can be had from the municipal power plant in case of necessity, and the pump is still available.

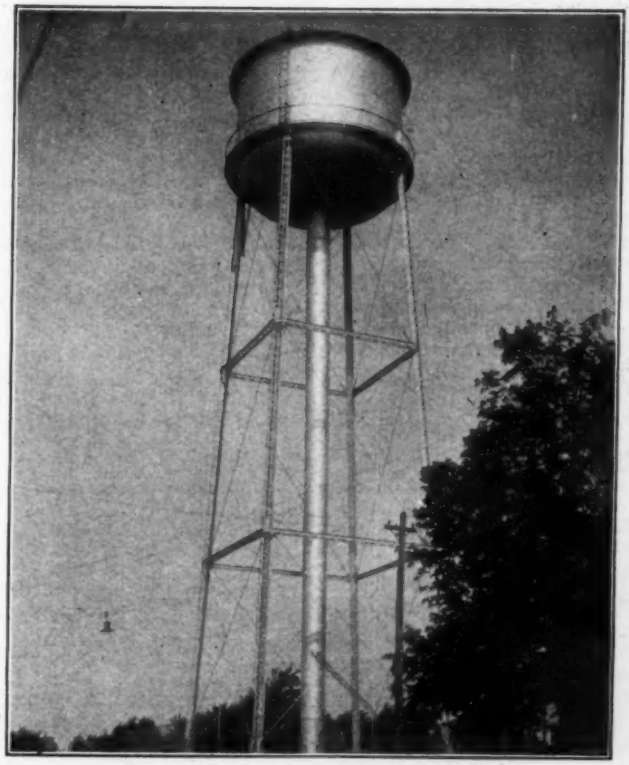
Another example is found in the City of Goshen, Indiana, where there has been installed a 500,000 gallon tank. The old plant was steam driven. About six years ago, the city installed a modern Diesel lighting plant, but only two of their deep well pumps were electrified at that time. The boilers had to be kept going at all times in the old steam plant, in order to have available suitable fire protection. In this case, a P.W.A. loan made it possible for Goshen to electrify its water works system. The city now has eight electric driven deep well pumps, and a new half million gallon tank. The loan by P.W.A. was negotiated on the basis of anticipated savings resulting from abandonment of the steam plant.

The cost of pumping for the old system on which boilers had to be kept up at all times, was given at approximately 8.3c per thousand gallons, which of course, was high, but the equipment was old, and used air lift pumps and double pumping, except for the two electric driven pumps.

It is estimated that the actual electrical pumping cost would be in the neighborhood of 1.2c per thousand gallons, and total cost at 2.2c per thousand. To take advantage of the potential saving (about 6c per thousand) an elevated tank had to be installed.

The old standpipe was not adequate for the demands, as the upper portion of this standpipe did not store very much water. The new elevated tank, of one-half million gallons, was installed some distance from the plant and on the opposite side of the city.

The entire pumping equipment is automatically controlled, there



The 50,000 Gal. Tank of Albion, Ind.
Will pay for itself in less than fifteen years.

*Excerpts from a paper written by Mr. Brossman shortly before his death. It was presented before the Indiana Section of A.W.W.A..

being two automatically controlled pumps at the tank site (about 1.5 miles from the main station), and six automatically controlled deep well pumps at the main station, each pump having a capacity of 500 G.P.M. Any pump can be manually started or stopped by push button control from the main plant.

Results at Goshen

Merle J. Miller, Superintendent and Manager of the Goshen plant, has made it possible for me to take the following from his report on the Goshen betterments.

"With a stand-pipe of the small capacity that we had previous to the erection of our new elevated tank, our water circuits were only fairly stable, but since the additional storage capacity has been added to our system, it has made a wonderful change in our water pressure charts as there is more cushion and no surge anywhere along the line. A number of charts taken at the elevated tank location have been absolutely perfect from the standpoint of surges or variation in pressure. We found before, especially with the steam pumping equipment, that we could detect each pulsation of the steam pump, as our standpipe capacity, at that time, was not enough to cushion the whole system properly. Comparing the old system as against the new system for uniform pressure, there is a vast difference. From the new system, if given any attention at all, we get a chart of uniform pressure, with as little variation as one pound.

"We also find a marked difference in the circulation of the water in districts where we had frequent complaints during the warm summer months against the warm stagnant water."

From the foregoing, it will be seen that in any plant that does not have an elevated tank, or if they have a standpipe of very small capacity, with very little water available in the upper section, the modern type of elevated tank, with all of the storage at the proper level, will almost invariably result in a financial saving, as well as give the other advantages which accrue to it.

Concerning Fire Protection Requirements

The relation of the elevated tank to fire protection is one of the important factors that should not be lost sight of. Modern elevated tanks, as compared to old standpipes, are much different for the available capacity for fire fighting facilities, as credit for water in a standpipe is only allowed for the top sections. Modern tanks, as now designed, keeps the water level to within a few feet variation, dependent more or less upon type of regulating control on the electric pumps.

Fire flows should not be confused with the total daily flow or capacity. For instance: if a town has a total available supply and storage based on a 24-hour period the fire flow will usually be based on a 5-hour flow for communities of 2,500 and less, which means that they will need 4.8 times the average consumption capacity as storage capacity for fire. For cities above 2,500 the multiplier will be 2.4 times for fire storage, as against consumer use storage. Such is based on a requirement of capacity for not less than a 10-hour period of continuous fire flow.

The fire flow requirements for average cities are given by the Underwriters, as follows:

Population	Required Flow (G.P.M.)
1,000	1,000*
2,000	1,500*
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000

* For 5 consecutive hours; all higher flows for 10 consecutive hours.

Therefore, in selecting the tank the fire flow for the period required, according to population, is the primary consideration. To this must be added the domestic consumption.

One of the Two 1,500,000 *Gal. Tanks of Indianapolis*
A leafy green and silver structure which constitutes a study in "neighborhood-treatment" of water towers.

This amount indicated is then balanced against the available low lift capacity of the pumps, such as wells or filters, also the ground storage capacity. The total low lift and ground storage capacity is then determined.

The second step is to figure the high lift pump capacity and the elevated storage capacity.

After these two quantities are known, they are compared to the required fire flow and domestic flow over the 5 or 10-hour period, as the case may be. This will then give the ideal condition in installed pumping capacity and tank size.

In case these conditions are not met, if there is a deficiency in pumping capacity or storage on either the low lift and ground storage or high lift and elevated storage, this deficiency will be taken into account in the making of rates.

It should be clearly kept in mind that the total 24 hours available capacity is not what is considered by the Underwriters. They base the capacity wholly on the fire flows listed for the period of hours noted.

Concerning Tower Heights

The matter of pressure from elevated tanks should not be lost sight of, as various pressures are required for certain types of buildings, according to the size town and construction therein.

One of the outstanding tank installations in this country, is that installed by the Indianapolis Water Company.

This large tank is located in the eastern section of Indianapolis, which is approximately 100 feet higher than their main pumping station. With this long line of pipe, and the ensuing friction losses, pressures were previously very low in this district. It was decided, after considerable study of ground as elevated storage, to erect an elevated tank with 1,500,000 gallons capacity to serve the approximately 64,000 people in this district. This tank has resulted in great improvement in pressure and supply, with an ensuing satisfaction to the water consumers.

This tank is the largest one in the state of Indiana on a public water supply, the tank being 72 feet to the bottom, and with this large capacity, having a range of only 25 feet between the upper and lower water levels. As the result of benefits noted the Water Company is undertaking a tank of like capacity in another section.*

In conclusion, I would state that there are many plants in which a study of water storage as well as pump efficiencies connected therewith, would result in a marked saving in the operation of such plants.

* Since the writing of this paper the second tank has been erected and placed in service. This installation, with the new Cathodic protection system for safeguarding its interior against corrosion, is fully described in the November, 1939 issue of "WATER WORKS AND SEWERAGE."

R. D. COLE MANUFACTURING CO.

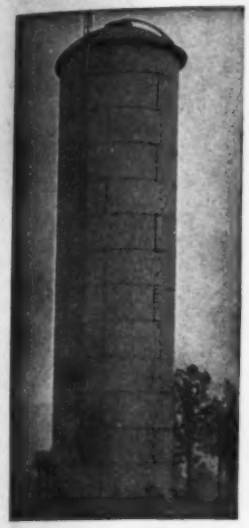
Est. 1854

Tanks, Towers, and Steel Plate Work
NEWNAN, GA.

5,000 TO 2,000,000-GALLON WATER TANKS

All shapes and sizes—The R. D. COLE MANUFACTURING CO. has developed a complete line of elevated steel tanks for water supply, both for domestic service and sprinkler requirements, ranging in capacity from 5,000 to 2,000,000 gallons.

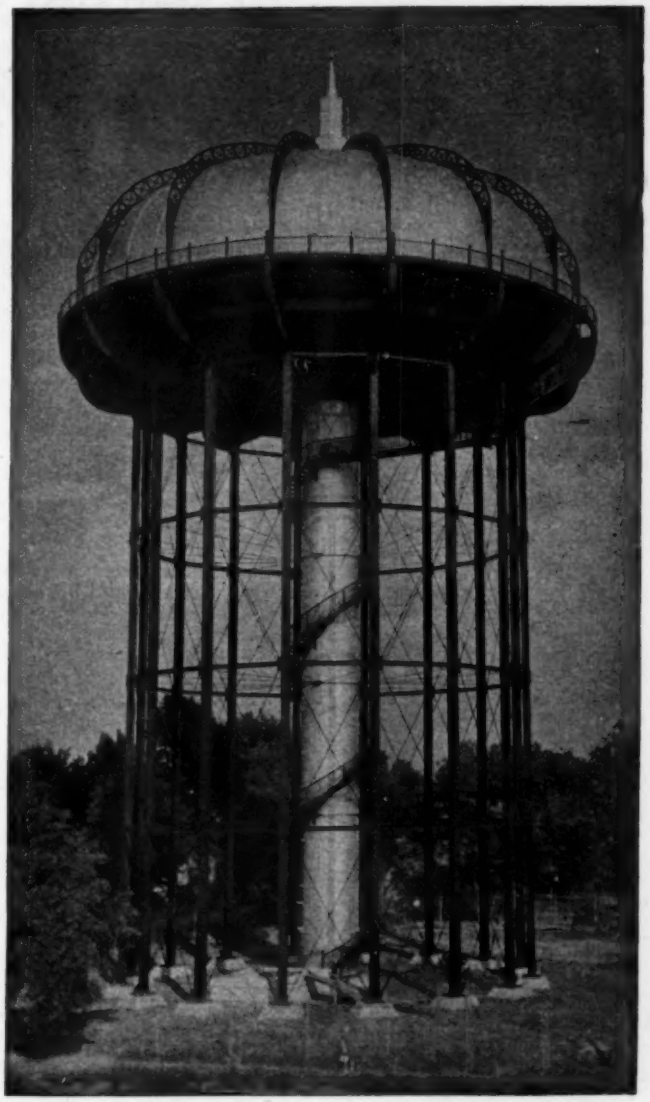
The designs include the standard Hemispherical Self-supporting Bottom, the "Cole Ovaloid," Standpipe and many individual styles involving architectural treatment to satisfy local conditions, or to provide special shapes for advertising purposes.



STORAGE TANKS

Pressure tanks for storage of gas from digesters at sewage disposal plants so that excess output at peak loads can be used during off-peak periods. Chemical storage tanks, hot water storage tanks, tanks for bulk storage of oils and gas.

Designs Available for Any Service



1,000,000-Gallon "Cole-Shallow Depth" Tank

CONSTRUCTION FACILITIES

Fabricated Steel Plate—The R. D. COLE MANUFACTURING CO. has a fully equipped plant for the fabrication of riveted or welded steel plate. In addition to the construction of its regular line of horizontal return tubular boilers, oil storage tanks, tubular heaters, etc., the company is prepared to construct special tanks and apparatus of any specified metal plate.

Alloys and Lining for Processing Apparatus—The facilities and experience of the company enable it to fabricate special apparatus of all kinds for the processing industry using alloy steel plates, stainless steel, nickel-clad steel, etc., or linings such as lead, tin, nickel or Monel.

ROSS VALVE MFG. CO., INC.

TROY, NEW YORK

AUTOMATIC CONTROL & PRESSURE REGULATING VALVES

***For* Water Works and Fire Departments**

For accurate service, the automatic control and pressure regulating valves must be right as to type and size for the service required. Our W. R. Type, cast iron, bronze mounted valves in sizes from 4″ to 30″ are guaranteed for services for which they are designed.

Altitude Valves

Single Acting

Model 40 AWR — semi-throttling hydraulic control to prevent overflow of tank, standpipe or reservoir or to maintain a positive adjustable head for washing and filtering operations. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Model 30 AWR—wide open or closed hydraulic control to prevent overflow of tank, standpipe or reservoir. Pilot adjustment range 4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other single acting altitude valves combine back pressure or relief valve and pressure reducing functions.

Double Acting

Model 40 DAWR—to prevent overflow in tank or reservoir and to allow return flow to distribution system when head on tank side is three inches higher than head of distribution system. These valves may be equipped with Remote Hydraulic and Electric Control. When required the return flow can be delayed for a predetermined pressure drop in distribution. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other double acting altitude valves combine many additional features to prevent dumping of tank, to retain supply on off peak loads and to make available maximum storage for peak load periods. Also a semi-throttling model for gradual closing of feed line and for maintenance of adjusted pressure on the distribution side. Can be equipped with secondary pilot to close valve if break occurs in distribution system.

Surge — Relief — Back-pressure Valves

Model 50 RWR—Single Pilot, Electric and Hydraulic Control—for protection against excessive pressures in distribution systems, supply lines and pump discharge lines. Installed in discharge line of deep well pump, provides constant back pressure to prevent overdrafting of the well. Pressure range in pilot—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.

Float Valve or Level Controller

Model 50 FWR—External Pilot Operated—to control main valve so that main stem operates wide open or closed. Pilot valve wastes to atmosphere contents only of operating chamber each time valve stem rises to open position. Maximum inlet pressure, 175 lbs.

Model 40 FWR—External Pilot Operated, Semi-throttling—for gradual closing of valve during last three inches before overflow.

Reducing and Regulating Valves

Model 40 WR—Single Pilot, Hydraulic Control—to maintain constant desired discharge pressure regardless of rate of flow or pressure on upstream side of valve. As a pressure reducing valve, operates to:

1. Control and regulate pressures in gravity and pumping systems.
2. Regulate flow between reservoirs and zones of different pressures.
3. Regulate fire flows between zones of unequal pressures.
4. Regulate pressures in filter wash lines and aerator nozzles.

Valves operate without waste of water to atmosphere and will not induce surge. Can be equipped with dual pilot to permit changing from one pressure to another by mere operation of a three-way cock for systems operating under different day and night pressures. Valves may be supplied with right-angle body. Pressure range outlet—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.

Model 40 WR—Single Pilot, Electric Remote Control—motor driven, geared to pilot adjusting tail screw, made with limit stops to prevent over-travel, and operated by push button switch.

Pressure Reducing and Reverse Flow Valves

Model 50 WR—Single Pilot, Hydraulic Control—for installation at dividing line between two zones to reduce pressure from higher zone, to function as a sleeping valve, discharging into low zone at a time of excessive draft, to permit flow from low to high zone when excessive draft in high zone reduces its pressure below that of the low zone as in case of fire. Pressure range outlet—15 to 60 lbs., 20 to 150 lbs. This valve may be equipped with dual pilot control to permit greater ranges in pilot control and to provide the assurance which goes with duplication and stand-by units.

FIRE DEPARTMENT SPECIALTIES

Portable Fire Hydrant Head for Pressure Reduction—Internal Pilot Operated—for attachment to high pressure main; carried on apparatus to fire, one man can attach (110 lbs. weight) in 18 to 30 seconds, four 2½″ hose connections delivering independently from shutoff to full pressure and a fifth connection 2½″ to 3″ delivering full pressure.

Hose Valves for Pressure Reduction
Fire Engine Relief Valves

All Ross Valves Repaired in Line: Internal Packing Replaced Through Top of Valves.

REPAINTING STEEL WATER TANKS*

(With Notes on Repairs)

THE appended material constitutes an outline for use in preparing repainting specifications. In using this outline, it will be necessary for the purchaser to insert the requirements for the number of coats to be applied and the kind and color of paint. These are variables, which depend upon the condition of the surface to be painted, the type of existing coating and the color. *Since these are "painting" specifications only, no reference is made to cathodic protection, which is, however, applicable to old as well as new tanks.*

Frequency of Painting

To assure long life and to prevent the formation of deep-seated rust or corrosion, steel tanks should be thoroughly inspected both inside and out at intervals not exceeding five or six years. Where paint is exposed to unusually severe atmospheric conditions or to corrosive water, more frequent inspection and repainting will be ncessary.

Number of Coats

If the old paint is in fair condition, only one coat may be required. It will probably be found, however, that, after cleaning, certain portions of the steel will be bare; these should be painted with a spot or patch coat before the finish coat is applied. If the surface is generally in bad condition, a complete primer coat should be substituted for the patch coat, in which event a total of two coats will be required on the entire structure. The extent of the painting or number of coats should be specified by the purchaser.

Inside of Tank

Experience has shown that, in practically all cases, the inside surfaces of a water tank are in worse condition than the outside. Almost without exception, tank bottoms which have had to be replaced on account of leaks through the steel, have corroded through from the inside. It is vitally important that the inside of a tank be painted as often as the exterior; and, if the water stored is particularly corrosive, the interior may have to be painted at more frequent intervals.

Kind of Paint

Underwater exposure involves very severe service for paint. The paint which, in general, has given the best results for this service is red lead and linseed oil paint (*weighing 21 to 24 lb. per gal.*) containing small amounts of lithargic, which acts as a hardener. This has not, however, been satisfactory for certain waters. Asphalt paints have been found suitable for some waters, but quite unsuitable for others. *Coal-tar enamels have also been widely used with generally satisfactory results where ice formation is not a factor.* More recently the newly developed synthetic resin type of paint has given good results under many conditions. Where experience with red lead and linseed oil paints containing litharge has been unsatisfactory, it is recommended that consideration be given to the alternate types. Where red lead and oil paints are used, it is not necessary to apply a finished coat over the red lead and the same paint may be used if a second coat is specified. In the event that two coats are necessary, however, a small amount of lamp black should be added to the second coat in order to give a darker shade and in this way to make it easier to determine whether the first coat has been entirely covered by the second.

If the old paint on the outside of the tank is black or dark green, a graphite paint may be used for the exterior surfaces. If the old paint is aluminum or a light colored paint, unless it is in fair condition, it may be necessary to apply two coats to insure a good finished appearance. If the final color desired is dark, the two coats may be necessary to cover the old light paint. If the final desired color is light gray, cream or some similar light color, the two coats will probably be necessary, as light paints do not have as good *hiding* power as dark paints. The paint used for the patch coat should be red lead or a similar suitable primer paint. If the finish coat is dark, the red lead for the patch coat should be darkened by the addition of lampblack, so that the patch areas may be successfully covered.

It is not the intention in these suggestions to recommend any particular brand or manufacturer of paints. The purchaser should consult *the tank manufacturer from whom the tank was purchased* or a reliable paint manufacturer of his own selection and determine which kind, quality and composition of paint to use, specifying the use for which it is intended.

Repairs

If any consideration is to be given to repairs to a tank at the time that it is being painted, the representative of a firm engaged in the installation of elevated water storage tanks should be called and directed to inspect the existing structure. *Non contract related to repainting water storage tanks should have made a part of it any agreement related to repair work unless a prior inspection of the tank has been made and the extent of and cost of the repairs is recorded in an aggregate figure.* Certain unscrupulous painting and repair firms have solicited painting work and, after inspection of the structure, have represented to the owner that expensive repairs were necessary. Quite frequently such firms have removed hundreds of perfectly good rivets in order to replace them at so much per rivet, or per hour.

Rivets

For a great many years it was the custom for tank manufacturers to drive tank rivets with flat heads on the inside. After a number of years a flat-head rivet, which may have rusted to some extent, appears to have lost the major portion of its head, when, in reality, only a small part has disappeared and the rivet has many years of life left. As rivets do their work in shear and as there is very little tension force in a rivet, the head can rust entirely away before replacement is necessary. As long as a rivet stays in its hole, it fulfills its function and does not have to be replaced.

Spider Rods

In the building of an elevated tank, it is the builder's custom to place rods across the top of the tank shell, under the roof, like spokes of a wheel. These are known as spider rods. As they are located near the high-water line and are alternately wet and dry, corrosion is severe and they may rust out long before the inside surfaces of the tank have been severely attacked. These rods are used for erection purposes only and may be removed, if desired, without harm to the structure. The tank builder does not recommend their replacement if they rust out. A tank repair man may claim the tank is in need of extensive repairs, after showing the owner these rusted rods. *Beware of the repair firm using the condition of the spider rods as a basis for recommending repairs.*

Leaks

If there are leaks in a tank, they may be of three kinds:

The first type is the leak through an expansion joint of a tank having the older type of cast-iron riser and wooden frost case. The remedy consists of repacking the expansion joint.

The second type is the leak at a calked joint or rivet head. Unless corrosion at this point is severe, this leak can be stopped by the use of ordinary hand calking tools.

The third type is a leak right through the plate at a point where a pit hole has eaten its way through. Such a leak may *ordinarily* exists only in the case of a very old tank or one which has not been cleaned and painted on the inside for about twenty years, *although there are rare cases of pit penetration in a shorter time due to electrolytic action or very corrosive water. In these cases the water should be analyzed and a check made to locate stray currents.* A temporary repair may be effected by the use of a patch bolt. Such a leak indicates that the entire bottom may be thin and other leaks may soon appear. The use of welding to patch such leaks is of very doubtful economy, as the heat of welding very often is the cause of new leaks. Even if a considerable area is welded, it may be but a short time after such repairs are made before new leaks appear. The only entirely satisfactory cure is the replacement of the entire bottom. This should be done by the manufacturer or by a regular tank construction company. If it is desired to postpone such replacement, leaks may be temporarily stopped with patch bolts as they appear and such repair may suffice for a few years.

Inspections

When a large water tank reached twenty years of age or more

*Tentative Recommended Practice by the American Water Works Association—Jour. A.W.W.A., July 1943.

and the owner suspects that maintenance has not been of the best, it would be advisable to have a complete inspection made. Usually the tank manufacturer has experienced men for this service, who, for a nominal charge, will submit a report showing the condition of all parts of the structure. In case of doubt as to the need of repairs, the manufacturer should be consulted.

Precautions

In painting the interiors of closed tanks, adequate ventilation should be provided to remove fumes and prevent injury to workmen or the possibility of accumulating volatile gases.

PROPOSED SPECIFICATIONS FOR REPAINTING ELEVATED STEEL TANKS AND WATER STORAGE TANKS

1. General

The contractor shall furnish all labor, machinery, tools, rigging, brushes and all cleaning and painting materials necessary to clean and paint the structure in strict conformity with the requirements of these specifications.

(If owner elects to furnish the paint, it shall be so stated at this point.)

2. Cleaning

All dirt, rust, loose mill scale and loose paint shall be removed by means of scrapers and wire brushes. *Special care shall be used to clean all pits and roughened areas.* If any rust forms on the cleaned surface it shall be entirely removed before any paint is applied.

All rust, scale and sediment collecting inside of the tank bottom shall be entirely removed and the inside surfaces swept clean. In the case of elevated tanks, such rust, scale, etc., shall be lowered to the ground by means of a bucket and rope.

(If the condition of the steel surface is such that the above means are incapable of properly cleaning the steel and sandblasting must be resorted to ,paragraph 3, below, shall be used in place of paragraph 2.)

3. Cleaning by Sandblast

If cleaning, as outlined under paragraph 2 above, is not effective, sandblast shall be used. In such case, the sandblast equipment shall be in good working condition and shall have ample capacity to furnish the required volume of compressed air at sufficient pressure to operate the sandblast effectively. The sand used shall be largely composed of silica grains and shall be sharp and as coarse as it is practicable to use. Provision shall be made to prevent the spreading of sand to adjoining property. All rust, mill scale, grease or other material shall be removed from the steel so as to expose the bright metal over the entire surface to be cleaned. No more area shall be sandblasted than can be painted on the same day that the cleaning is done. If rust forms on the cleaned surface, from any cause, it shall be removed before any paint is applied.

4. Quality of Paint

The paint to be used shall be ready-mixed and shall arrive at the job in the original sealed cans or drums, bearing the manufacturer's name. *Two pounds* of litharge shall be added to *each gallon* of red lead paint used on submerged surfaces. *Litharge shall be added only to such quantity of paint as will be applied within the half day following. No paint containing litharge shall be used if it has stood overnight.*

The brand or manufacturer of the paint shall be as agreed upon between the purchaser and contractor, it being understood that only the best grade of paint, from well known, reliable paint manufacturers, will be used. No paint shall be applied until approved by the authorized representative of the customer. Heavy pigment paints shall be well stirred each time before paint is withdrawn from a large container. If the pigment shows a tendency to settle, frequent stirring is necessary during the painting operation. If the paint is too heavy for use, it shall be thinned with *such thinner as the manufacturer may specify for the particular paint used. (No gasoline or benzene shall be used.)*

5. Application

The number of coats, color and kind of paint shall be specified by the customer. The first coat of paint shall be applied to the cleaned and perfectly dry surface before rusting begins. Additional coats shall be applied only under favorable conditions. All paint shall be applied by skilled painters and shall be carefully brushed out to a thin uniform coating, working carefully around rivet heads, joints and other irregularities in the surface. Each coat shall be allowed to dry thoroughly before the next coat is applied. Paint shall be applied only when the air temperature is at or above 40° F. It shall not be applied during wet or foggy weather or upon damp surfaces or upon metals containing frost.

FLOW IN HOUSE SERVICE PIPES

Condition of Discharge	Pressure in Main Pounds per Square Inch	Discharge in Cubic Feet per Minute from the Pipe — Nominal Diameters of Iron or Lead Service Pipe in Inches								
		½	⅝	¾	1	1¼	2	3	4	6
Through 35 ft. of service pipe; no back-pressure.	30	1.10	1.92	3.01	6.13	16.58	33.34	88.16	173.85	444.63
	40	1.27	2.22	3.48	7.08	19.14	38.50	101.80	200.75	513.42
	50	1.42	2.48	3.89	7.92	21.40	43.04	113.82	224.44	574.02
	60	1.56	2.71	4.26	8.67	23.44	47.15	124.68	245.87	628.81
	75	1.74	3.03	4.77	9.70	26.21	52.71	139.39	274.89	702.03
	100	2.01	3.50	5.50	11.20	30.27	60.87	160.96	317.41	811.79
	130	2.29	3.99	6.28	12.77	34.51	69.40	183.52	361.91	925.58
Through 100 ft. of service pipe; no back-pressure.	30	0.66	1.16	1.84	3.78	10.40	21.30	58.19	118.13	317.23
	40	0.77	1.34	2.12	4.36	12.01	24.59	67.19	136.41	366.30
	50	0.86	1.50	2.37	4.88	13.43	27.50	75.13	152.51	409.54
	60	0.94	1.65	2.60	5.34	14.71	30.12	82.30	167.06	448.63
	75	1.05	1.84	2.91	5.97	16.45	33.68	92.01	186.78	501.58
	100	1.22	2.13	3.36	6.90	18.99	38.89	106.24	215.68	579.18
	130	1.39	2.42	3.83	7.86	21.66	44.34	121.14	245.91	660.36
Through 100 ft. of service pipe and 15-ft. vertical rise.	30	0.55	0.96	1.52	3.11	8.57	17.55	47.90	97.17	260.56
	40	0.66	1.15	1.81	3.72	10.24	20.95	57.20	116.01	311.09
	50	0.75	1.31	2.06	4.24	11.67	23.87	65.18	132.20	354.49
	60	0.83	1.45	2.29	4.70	12.94	26.48	72.28	146.61	393.13
	75	0.94	1.64	2.59	5.32	14.64	29.96	81.79	165.90	444.85
	100	1.10	1.92	3.02	6.21	17.10	35.00	95.55	193.82	519.72
	130	1.26	2.20	3.48	7.14	19.66	40.23	109.82	222.75	597.31
Through 100 ft. of service pipe and 30-ft. vertical rise.	30	0.44	0.77	1.22	2.50	6.80	14.11	38.63	78.54	211.54
	40	0.55	0.97	1.53	3.15	8.68	17.79	48.68	98.98	266.59
	50	0.65	1.14	1.79	3.69	10.16	20.82	56.98	115.87	312.08
	60	0.73	1.28	2.02	4.15	11.45	23.47	64.22	130.59	351.73
	75	0.84	1.47	2.32	4.77	13.15	26.95	73.76	149.99	403.98
	100	1.00	1.74	2.75	5.65	15.58	31.93	87.38	177.67	478.55
	130	1.15	2.02	3.19	6.55	18.07	37.02	101.33	206.04	554.96

(Courtesy, Buffalo Tank Corp.)

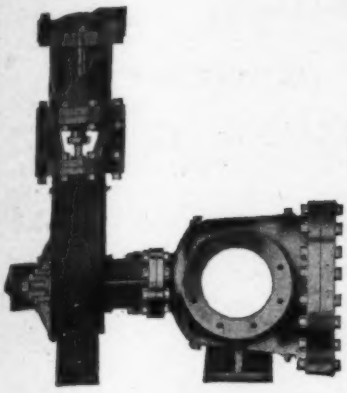
DISCHARGE BY SPRINKLER HEADS

No. of Sprinklers	Pressure in Lbs. per Square Inch at Sprinkler						
	5	10	15	20	25	30	35
1	14.	18.	22.	25.	28.	31.	33.
2	27.	36.	43.	49.	55.	61.	66.
3	41.	54.	65.	74.	83.	92.	100.
4	54.	72.	86.	99.	110.	123.	133.
5	68.	91.	108.	124.	138.	154.	166.
6	82.	109.	130.	148.	165.	184.	199.
7	95.	127.	151.	173.	193.	215.	232.
8	109.	145.	173.	198.	220.	246.	266.
9	122.	163.	194.	222.	248.	276.	299.
10	136.	181.	216.	247.	275.	307.	332.
20	272.	362.	432.	494.	550.	614.	664.
30	408.	543.	648.	741.	825.	921.	996.
40	544.	724.	864.	988.	1,100.	1,228.	1,328.
50	680.	905.	1,080.	1,235.	1,375.	1,535.	1,660.
60	816.	1,086.	1,296.	1,482.	1,650.	1,842.	1,992.
70	952.	1,267.	1,512.	1,729.	1,925.	2,149.	2,324.
80	1,088.	1,448.	1,728.	1,976.	2,200.	2,456.	2,656.
90	1,224.	1,629.	1,944.	2,223.	2,475.	2,763.	2,988.
100	1,360.	1,810.	2,160.	2,470.	2,750.	3,070.	3,320.
200	2,720.	3,620.	4,320.	4,940.	5,500.	6,140.	6,640.
300	4,080.	5,430	6,480.	7,410.	8,250.	9,210.	9,960.
400	5,440	7,240.	8,640.	9,880.	11,000.	12,280.	13,280.
500	6,800.	9,050.	10,800.	12,350.	13,750.	15,350.	16,600.
1000	13,600.	18,100.	21,600.	24,700.	27,500.	30,700.	33,200.
2000	27,200.	36,200.	43,200.	49,400.	55,000.	61,400.	66,400.
3000	40,800.	54,300.	64,800.	74,100.	82,500.	92,100.	99,600.
4000	54,400.	72,400.	86,400.	98,800.	110,000.	122,800.	132,800.
5000	68,000.	90,500.	108,000.	123,500.	137,500.	153,500.	166,000.

GOLDEN-ANDERSON VALVE SPECIALTY CO.

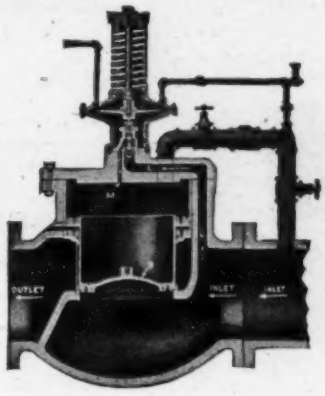
1350 Fulton Bldg.

PITTSBURGH, PENNA.



THRU-FLOW CONE VALVE

Afford full pipe line flow without friction loss. Always oil lubricated. Axially unseats before it rotates without friction, rub or wear. Especially desirable for sewage disposal service.



ALTITUDE CONTROL VALVE

Assures uniform water level in tanks, standpipes and reservoirs. Suitable for use in single or two-way line service. Heavy internal bronze mounting and air and water cushioning makes valve indestructible. Sizes to 24".

CUSHIONED FLOAT VALVE

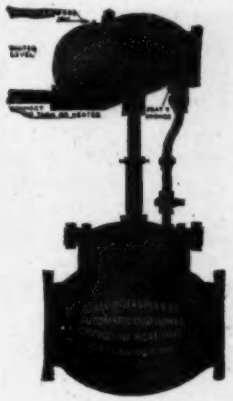
Automatically maintain uniform water levels in tanks, standpipes, etc.

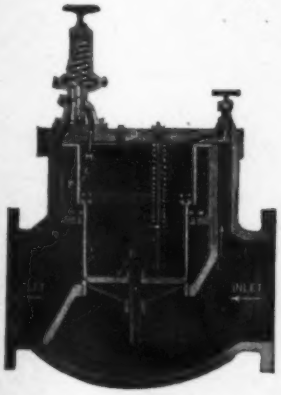
Instantly adjusted to operate quickly or slowly.

Cushioned by water and air, sizes ½ to 24".

CONTROLLING FLOAT VALVE

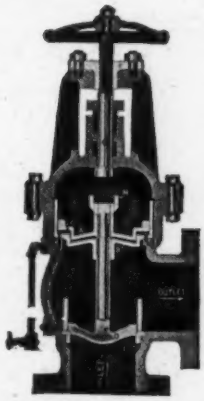
Ideal for heaters, vats, tanks, etc. Valve entirely self-contained and operates without water spill. Sensitive in operation and indestructible due to air and water cushioning and heavy bronze mountings. Sizes to 24".





WATER REDUCING VALVE

Assures positive control of low pressure. Air and water cushioning prevents shock or hammer. Supplied with single or dual pilot controls for any service. Sizes to 24".

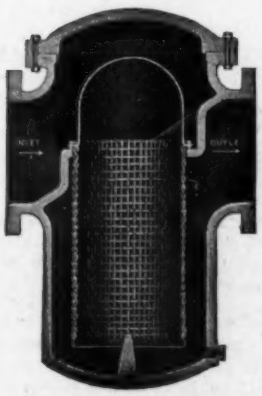


NON-RETURN VALVE

Protect life and property against boiler tube ruptures; also, furnished in Triple Acting style to protect against steam line breaks. Supplied for low and high pressure steam service. Sizes to 12" in angle, globe or elbow patterns.

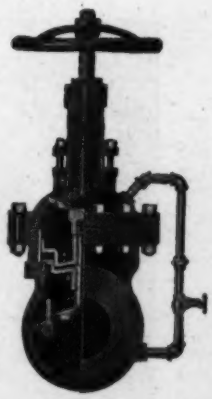
WATER STRAINER

Large capacity with minimum friction loss. Strainer basket quickly accessible and easily cleaned. Basket mesh furnished to suit any service conditions. Sizes to 24".



ENGINE STOP VALVE

The most efficient and dependable automatic stop valve to prevent overspeeding of turbines, engines, etc. Automatically tripped by mechanical or electrical control. Furnished angle or globe patterns to 12" sizes.



S. F. FERGUSON

11 HILL STREET NEWARK 2, NEW JERSEY

"UNIVERSAL" WATER LEAK DETECTORS AND PIPE LOCATORS
BOB WHITE ELECTRONIC BOX LOCATOR

"UNIVERSAL" WATER LEAK SURVEY INSTRUMENT

Water under pressure, escaping through an orifice sets up vibrations which are radiated out over the distribution system and up through the ground. The average person cannot detect and spot the point of origin of these vibrations without some means of measuring their amplitude.

The "Universal" Leak Detector picks up these feeble vibrations, amplifies them many times and then records their amplitude on a meter. This instrument is carefully tuned to the vibrations given off from water leaks, thus reducing interference from outside noises.

Under the proven "Ferguson Method" of water leak survey, all unnecessary practices of the past have been eliminated, such as digging and tapping the main, shutting off valves, digging dry test holes, etc.

EQUIPMENT consists of: One super-power, converter type amplifier; one VP-8 microphone with adjustable hydrant cap; one pair crystal headphones; one steel carrying-case for above; one 25-ft. rubber-covered cable with polarized plugs; one A to B power converter; one steel carrying-case for above; one 120 ampere hour, storage battery with steel handle; one set steel rods, cadmium plated.

"UNIVERSAL" ENERGIZER TYPE PIPE LOCATOR

When using the energizer type of pipe locator, it is necessary to energize the pipe to be located, with either single or double induction. Single induction means that only one wire is attached to the pipe and the other wire is grounded to a rod driven into the ground. This single induction is used when locating services.

Double induction is used to make a circuit. In this case each wire is attached at two separate places and the operator can locate the pipe between the two contact points.

EQUIPMENT consists of: one high-gain amplifier unit; one loop aerial complete with loop handle; one pair headphones; one steel carrying case, wrinkle finish, with built-in inductor coil and permanently connected leads, battery compartment and batteries.

The high-gain amplifier is stepped up to eliminate heavy batteries so that it weighs only 12½ lbs. The batteries are fitted with polarized plugs, making it impossible to connect new batteries improperly when replacement is necessary.

"UNIVERSAL" T-R TYPE PIPE LOCATOR

Especially designed to locate lost pipe, short stubs, buried gates, tees and crosses, short services, covered valve boxes.

No energizing or electrical circuit needed to locate the exact center line of any size pipe, up to depths of 12 feet. Any average workman can walk anywhere on the distribution system and immediately locate services, short stubs, valves, etc.

EQUIPMENT consists of: one transmitter type unit with self-contained batteries and tubes; (this unit has battery volt meter and balance adjustment, with a red warning light, all mounted on the panel); one receiver type unit with self-contained batteries and tubes; (this unit also carries a battery volt meter on the panel, and a special indicator meter is used on this unit to give accurate center line indications). Light weight crystal headphones are used in conjunction with the receiver.

The two units are shipped in a leatherette covered carrying case. Total shipping weight, 48 lbs. Both units operate on dry cell A and B batteries. Batteries and tubes can be replaced by your local radio man.

Bob White ELECTRONIC BOX LOCATOR

This new Electronic Box Locator was developed for accurate, speedy location of buried curb, meter, valve and drip boxes, manhole lids, sewer clean-outs and lamp-holes.

The illustration pictures an operator as he walks along swinging the locating disc (loop aerial) a short distance above ground or paving. Above or at the edge of a metal box-lid, the amplifier worn over the shoulder sends the bob-white signal to the ear phone. The signal is so audible that the earphone may be carried in the pocket of the operator. As soon as the edge of the loop disc is over one edge of a box cover, the signal sounds. Thereafter, by swinging or rotating the disc the exact center of the box may be located and the spot marked for digging.

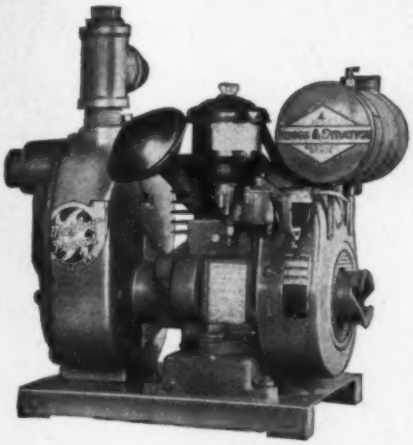
The "Bob-White" is not affected by a snow or ice covering, small bits of metal, overhead wires, electrical fields or passing automobiles, as some other locators are. A 4-inch curb box may be located 6 to 10 inches under ground surface, an 8-inch box 8 to 10 inches, and a manhole cover through 12 to 14 inches of cover.

NORTHROP & COMPANY, INC.

Water Works Specialties and Supplies

50 Church Street • NEW YORK 7, N. Y.

MARLOW Self-Priming Pumps



1½" — $90.00

Give Instant Performance

This powerful little unit is the last word in lightweight self-priming pumps. Available now in case iron weighing 83 lbs. — after the war in aluminum. Powered by a 1 H.P. Briggs & Stratton 4-cycle engine, it will pump 15,000 to 20,000 gallons on one gallon of fuel. It has a capacity of 3,000 gals. per hour and an open impeller to handle dirty water.

Other self-priming pumps from 1½" to 10" and a complete line of diaphragm and plunger pumps are available. Write for new pump catalog.

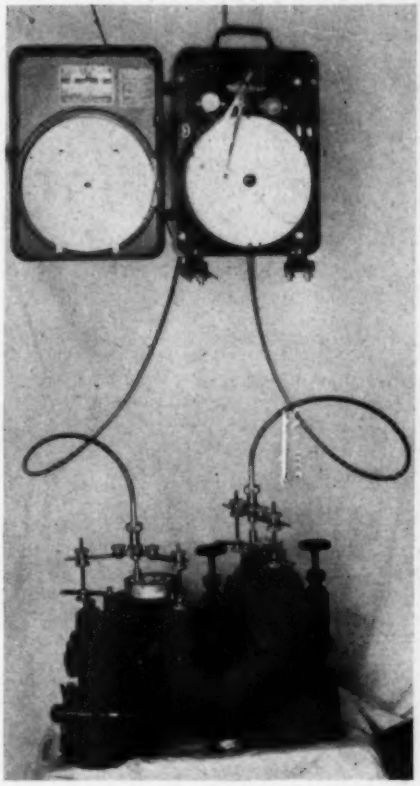
The NEW AQUA-MAGNETIC VALVE-BOX LOCATOR

A sensational new type magnetic valve-box locator now being used by waterworks and utilities companies all over the country. Makes child's play out of locating lost and buried valves and shut-offs. Can be read from standing or walking position, as it is carried along in genuine leather carrying case with shoulder strap . . . no stooping or kneeling.

Genuine 35% cobalt alloy steel needle, air-dampened to eliminate flywheel action . . . sapphire jewel bearings . . . gum rubber mountings to protect needle from jolts that tend to demagnetize needle . . . accurate, sensitive compass. Case has chrome-nickel handle for use under shrubbery, etc. Sent out on free 15-day trial.

THE METER MASTER

A Rate Recorder for Water Meters



Attach a Meter-Master in five minutes to any meter, single or compound, which is already in service. Use the six-hour clock and secure a definite and complete record of the rates of flow. Many times a smaller size meter will be adequate and thus you will save on cost of meter and increase your revenue at the same time. The Meter-Master is readily portable, weighing but 17 lbs. and requires no current or batteries for operation.

Types of Meter-Masters:

1. The 6- and 24-hour Round Chart Instrument—preferable for all-'round use by the smaller departments, using the 6-hour rate for obtaining peak loads and the 24-hour rate for general investigations and complaint work.
2. The 24- and 72-hour Round Chart Instrument—preferable for general investigations and complaints, using the 72-hour rate when records for more than 24 hours are desired, and over week-ends.
3. The Strip Type Instrument with its great range of chart speeds, which may be used for all kinds of investigations.

The GEOPHONE LEAK LOCATOR

$75.00

Complete with carrying case and strap.

OTHER PRODUCTS

Portable Compressors, Stationary Compressors, Pneumatic Tools, Thawing Generators, The "Flow-O-Meter", Leak Locators, Pipe Finders, The Meter-Master, Air Valves, Pipe Cutters, Pipe Pushers, Repair Couplings, Steam Thawers, Gauge Testers, Meter Boxes and Yokes, Valve and Curb Boxes, Meter Testers, Meter Seals and Books, Lanterns and Torches, Slide Comparators, Water Analyzer, Color Standards.

THE NATIONAL WATER MAIN CLEANING COMPANY

Contractors for Cleaning of Water Mains

22nd Floor, 30 Church St., New York, N. Y.

BRANCHES

115 Peterboro St., Boston, Mass.
910 William-Oliver Bldg., Atlanta, Ga.
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406 Florida Theatre Bldg., Jacksonville, Fla
3812 Castellar St., Omaha, Neb.
205 W. Wacker Dr., Chicago, Ill.
501 Howard St., San Francisco, Calif.
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THE NATIONAL METHOD

THE METHOD

The National Method of water main cleaning consists of passing a machine through the main which removes tubercles, incrustations and deposits from the pipe lining. This machine is either water-propelled or cable-drawn through the water main. Thorough cleaning can be accomplished by this method at the rate of approximately 50 to 100 ft. per minute, in sections of from several hundred feet to several miles depending upon conditions.

Briefly, the method involves cutting the pipe in two places, for entry and exit of the cleaning machine, inserting the machine; placing a riser pipe at the exit through which first the muddy water and then the machine emerge; propelling the machine by pressure or by cables through the pipe; finally shutting off the water, removing the riser pipe, and reconnecting the main.

The total time required for shutoff of water in any district is five to seven hours. In an emergency, the pipe can be temporarily made up and service resumed. The work can be done at night if desired.

20" Main in a Midwest City Before Cleaning.

THE RESULTS

The National Method is guaranteed to restore the carrying capacity of pipe to at least 95 per cent of that of new main (The actual result is usually very close to 100 per cent.)
The National Method gives you:

1. **Greater delivery**
2. **Lower pumping costs**
3. **Reduced insurance rates**
4. **Clean water**

LET US CLEAN OUT YOUR CLOGGED MAINS

National experience makes satisfactory cleaning certain. National men know how to meet and overcome unforeseen difficulties that may arise.

When a Pipe Lining Is Tuberculated to This Extent, the Frictional Resistance to Flow Is Considerable.

Machine Arrives at End of Run After Cleaning 30" Main in St. Louis

Information regarding any of the hundreds of successful cleaning projects will be supplied upon request.

DETERMINING THE CONDITION OF MAINS

How to Watch Your "C" Line for Friction Losses

By D. R. TAYLOR
Plant Superintendent, Water Department
Roanoke, Virginia

THERE are men who report to their physicians regularly for physical examinations. These men are not concerned about the surface of their anatomy—they can see that; they want to know the trend of that part of their "human plant" that is under the surface.

Among other things, they want to know the friction loss in their circulatory system, and if an increase of this friction is causing a diminution of capacity and a corresponding dissipation of power. They are anxious to take immediaate and proper remedial action if the friction is building up too fast and capacity is falling.

How Are Your Water Arteries?

Realizing that probably 80% of the worth of your water works "anatomy" is represented by its "arteries," also hidden under the surface, leads to the question—How *old* are your water supply arteries? And I do not mean in years, but in the matter of "oldness" in terms of that all important criterion—friction build up and failing capacity. Only if you are watching your "C" line will you know; otherwise you can only be guessing.

How to Find Out

The "C" Line I refer to is no other than the important line to show the status and trend of the coefficient of friction of pipe lines which you have frequently heard referred to as the "C" value of mains.

Determination of the "C" value derived from the famous Williams & Hazen formula may sound formidable and difficult but it really is not and I hope to be able to convince you of as much by showing how relatively simple it is to secure the needed test readings on a length of main and derive therefrom the "C" value (friction coefficient). In short, how you can answer the question—How old are your "arteries"?

This type of work is not only interesting but is full of surprises. It is the most positive and effective method of determining the necessity for reducing the friction in these important arteries and the need for treatment to prevent corrosion. Then, afterwards, what the results of such treatment are. Likewise, if there are advantages to be gained in the use of lined pipe. Finally, as an added guide in planning future developments and additions. After you have selected and tested sections of representative mains, you will have enough curiosity to make a second test within six months, after which an annual check-up is usually sufficient, depending upon results obtained.

The computations necessary are not as intricate as the average water works operator seems to think they are. You need not worry about being "rusty" in the use of a slide rule and unfamiliar with logarithms. You do not need to have a dizzy spell when you see the formidable looking formulae.

A Simple Method of Finding "C" Values

Herewith is a tabulation of diameters and areas of both pit cast and super deLavaud Cast Iron pipe which is self-explanatory, and, although "slipped off" on a slide rule, is sufficiently accurate for the work. I am also enclosing a data sheet presenting two logarithmic curves, the necessary formulae, conversion factors and explanation of symbols. These are all that I find necessary for ordinary purposes in solving flow problems.

In the upper right hand corner of the graph sheet are the simple formulae for determining quantity, velocity, and areas. Formula (1) in the center of the sheet is the original Williams and Hazen formula for the solution of velocity. It is more simply expressed in formula (2). Formula (3) is that employed in calculating these "C" values. Formula (4) is for the solution of "S," which represents hydraulic slope or friction loss. Formula (5) gives the same value more simply.

Procedure

Suppose that you are testing a section of unlined pit cast main with a nominal diameter of 10 inches. Say it is 800 feet long between pressure gauges, and that the measured rate of flow from the hydrant at the far end was 1036.8 gallons per minute. Let us say that the pressure drop between stations (shown by the difference in readings of the two pressure gauges) was 7.13 lbs./sq. in. This represents the friction loss (S) for the 800 ft. run between these two points.

Now, what is the coefficient of friction ("C" value) of this main?

By reference to the formulae on the data sheet we will find that

$$Q = 1036.8 \text{ g.p.m.}$$

$$Q = \frac{1036.8}{448.83} = 2.31 \text{ c.f.s.}$$

$$V = \frac{Q}{A} \text{ and } A = .5454$$

(10" pipe table 1.)

$$V = \frac{2.31}{.5454} = 4.225 \text{ ft./sec.}$$

The hydraulic radius of 10" pipe
$R = .2083$ (from table).

Friction loss (hydraulic slope)
$S = 7.13$ lbs./sq. in. (for 800 feet).

Convert to feet loss
$= 7.13 \times 2.31 = 16.47$ feet.

Per foot of main:

$$S = \frac{16.47}{800} = .0206.$$

Now for the formula:

$$C = \frac{V}{1.318\ R^{.63}\ S^{.54}} \text{ in which}$$

$$R^{.63} = .2083^{.63}$$

Although shown in the table, this value can be secured from the graph as follows: On the base line, we locate .2083 (R). From this point, move vertically up the sheet to intersect diagonal "B"; thence horizonally to the vertical axis, where we find 0.372. Therefore $.2083^{.63}$ is 0.372.

In a similar manner, by intersecting diagonal "A," by following up the .0206 (S) line from the base, we find:

$$S^{.54} = (.0206^{.54}) = .1225.$$

Therefore; according to the formula,

$$C = \frac{4.225}{1.318 \times .372 \times .1225} = 70.3.$$

In use of formula (5), by employing cure "A" "in reverse," any number raised to the 1.85185th power can be had.

For instance, using the above values in formula (5)

$$S = \left(\frac{4.225}{1.318 \times 70.3 \times .372}\right)^{1.85185} = .1225^{1.85185}$$

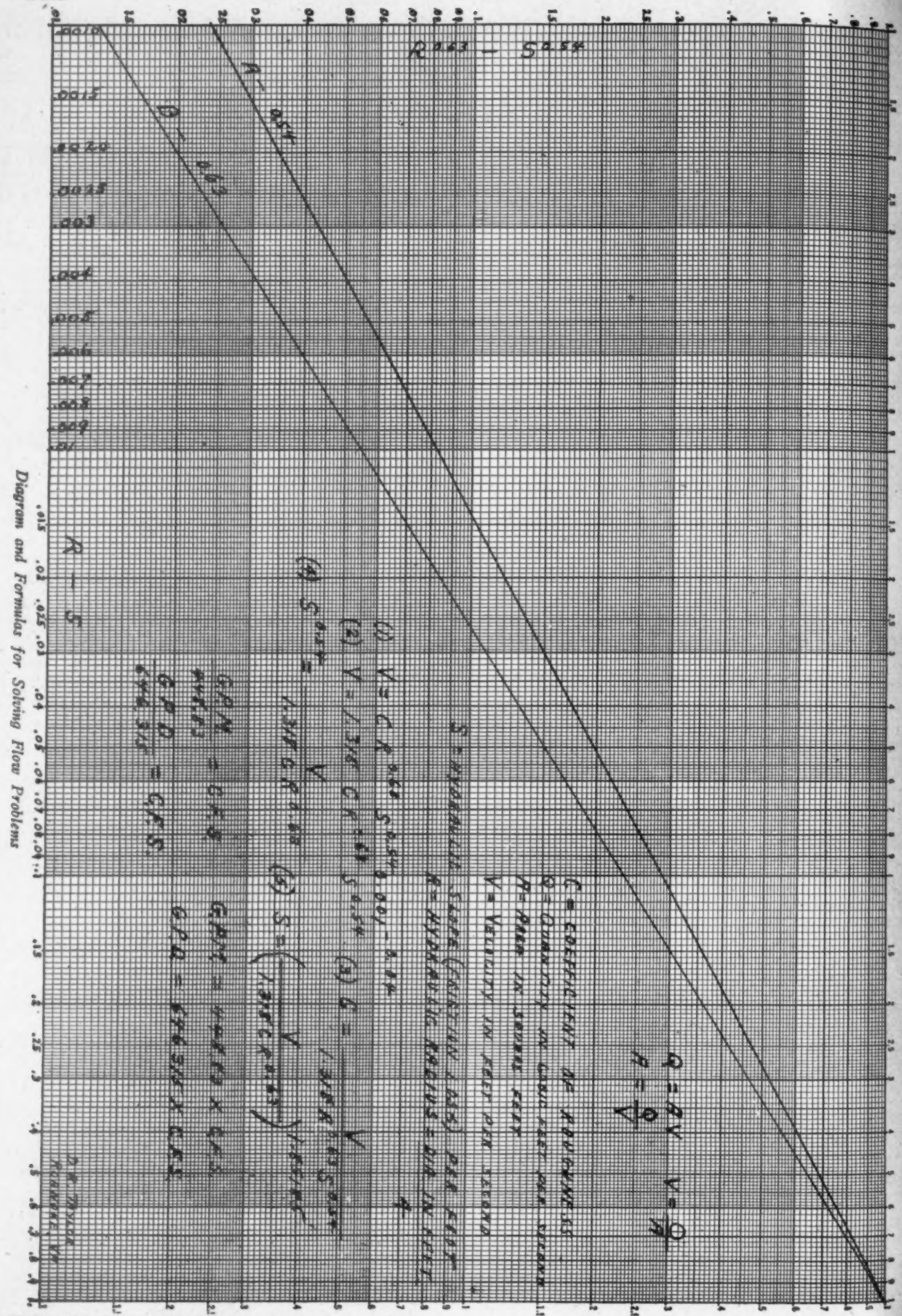
Find .1225 on the vertical axis, move horizontally to the right to diagonal "A" and then drop down to the base line, and we find .0206.

Therefore; $S = .0206$.

In order to be as brief as possible this explanation may require a little close study. However, the information should prove sufficient for fairly accurate evaluations.

Let me warn you though to caliper the hydrant nozzle through which the rate of flow is determined. Contrary to the common assumption, this diameter is rarely exactly 2½ inches.

If, after you have pursued this task for a while, your enthusiasm becomes more acute and the magnitude of your study warrants it, you might purchase two calibrated precision altitude gauges to replace your pressure gauges and a K. & E. log-log duplex decitrig slide rule, which is not nearly as difficult to use as you might think. With the use of the log-log scales on this rule, you can accurately and quickly determine the fractional powers


R = S
Diagram and Formulas for Solving Flow Problems
W. W. & S. — Reference & Data — 1944

or roots of numbers, and the decimal points are shown in each case. Furthermore, if all of this eventually leads to a complete comprehensive study of your entire distribution system, the purchase of an hydraulic slide rule (based on the Williams and Hazen formula) will be a good investment. With any great volume of hydraulic computations to be done, the answers can be rapidly determined with one of these rules, which is just as easy to use as the ordinary slide-rule.

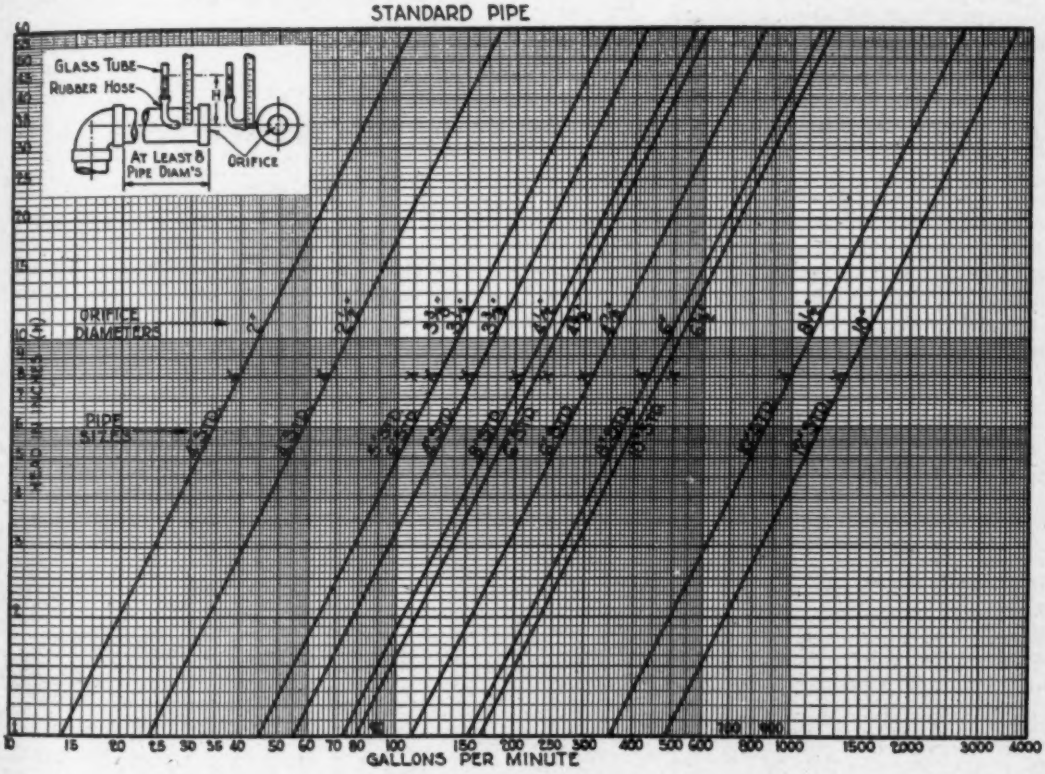
CAST IRON PIPE DIMENSIONS
and Hydraulic Radius Values

TABLE 1.

Nominal Diameter	Nominal Standard Dimensions All Cast Iron Pipe: Area Sq. Ft.	Diam. Feet	$R = \left(\frac{\text{Diam. Ft.}}{4}\right)$	$R^{.625}$	Actual Standard Dimensions: Pit-Cast Class B, Unlined: Area Sq. Ft.	Diam. Feet	Pit-Cast Class B, Cement Lined: Area Sq. Ft.	Diam. Feet	Super Delavaud Class 150, Unlined: Area Sq. Ft.	Diam. Feet	Super Delavaud Class 150, Cement Lined: Area Sq. Ft.	Diam. Feet
2".....	.0218	.1667	.0417	.135	.0218	.1667	.0192	.1562	.....	....	.....	....
3".....	.0491	.2500	.0625	.175	.0532	.2600	.0490	.2495	.0539	.262	.0495	.251
4".....	.0873	.3333	.0832	.209	.0915	.3418	.0825	.3240	.0920	.342	.082	.322
6".....	.1963	.5000	.1250	.270	.2060	.5120	.1890	.4900	.207	.513	.190	.492
8".....	.3491	.6667	.1665	.324	.3520	.6690	.3300	.6490	.367	.685	.346	.663
10".....	.5454	.8333	.2083	.372	.5420	.8300	.5150	.8100	.562	.8465	.536	.826
12".....	.7854	1.0000	.2500	.417	.7820	.9960	7500	.9760	.812	1.016	.780	.996
14".....	1.069	1.1667	.2917	.460	1.065	1.1640	1.005	1.132	1.152	1.212	1.100	1.180
16".....	1.396	1.3333	.3330	.500	1.398	1.3320	1.332	1.302	1.500	1.382	1.440	1.352
18".....	1.768	1.5000	.3750	.539	1.768	1.5000	1.700	1.470	1.890	1.550	1.820	1.520
20".....	2.182	1.6667	.4167	.576	2.182	1.6670	2.100	1.635	2.340	1.725	2.250	1.692
24".....	3.142	2.0000	.5000	.647	3.142	2.0000	3.060	1.972	3.350	2.062	3.25	2.035
30".....	4.909	2.5000	.6250	.744	4.880	2.4950	4.720	2.451	....	....	....	....
36".....	7.069	3.0000	.7500	.834	7.080	3.0000	6.840	2.958	....	....	....	....

FLOW MEASUREMENTS WITH THE CIRCULAR ORIFICE AT END OF PIPE

(*Peerless Pump Bul.*)



To obtain an accurate result in measuring the flow of water with a circular orifice the following conditions are to be maintained: Pipe must be horizontal with no elbows, obstructions or bends within 8 pipe diameters of discharge end; the orifice must be running full of water and "H" be at least one inch above top of the pipe.

Drill and tap discharge pipe on the side through center line for ¼" pipe connection one foot back from orifice. It is very important that the ¼" nipple does not extend inside the inner wall of the pipe and should be absolutely flush.

When the rubber hose connection and the glass tube are installed "H" may be measured from the center of the pipe with an ordinary rule.

HILL-HUBBELL and COMPANY

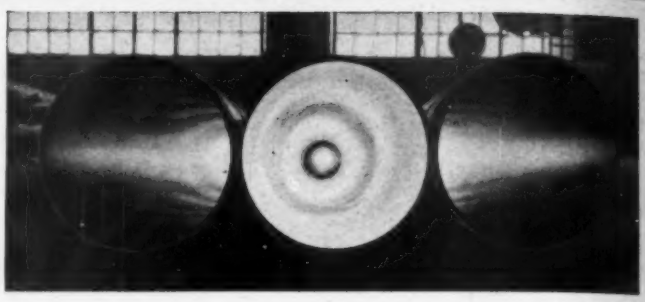
DIVISION OF

GENERAL PAINT CORPORATION

STEEL PIPE PROTECTION for Water Mains and Supply Lines

CLEVELAND, OHIO

The HILL-HUBBELL PROCESS of STEEL PIPE PROTECTION is on a MACHINE APPLIED PRODUCTION BASIS . . . .



BITURINE AKWALINE ASSURES HIGH "C" FACTOR

BITURINE AKWALINE ENAMEL is melted and heated in mechanically agitated and thermostatically controlled bitumen kettles. For lining STEEL PIPE, the duration of heating is kept to a minimum by the rapid application to the inner surface of the horizontally positioned power rolled or spun pipe. The feed line placed at the bottom of the pipe, disperses the flow of hot enamel in quantities sufficient to build up a multiple application thus covering and protecting the inner wall of the pipe with a smooth, resilient surface.

BITURINE ENAMEL COATING and KRAFT PAPER WRAPPING

BITURINE AKWALINE PRIMER is the first process in the protection of the pipe surface. Rapidly rotating weighted bristle brushes force the primer into every irregularity of the steel structure. BITURINE AKWALINE COATING—AND—WRAPPING is also machine applied; again minimum duration of heating is attained by exceptionally rapid application—After the second coating is applied there are no skips, holidays or bubbles, the felt wrapper is applied by flooding the inner surface with the hot coating, before it is wound on the pipe under fixed mechanical tension. Another coating is applied before the protective cover of 80 lb. Kraft Paper is spirally wound in place. HILL-HUBBELL AND COMPANY printed on the Kraft paper covering stamps it a product of worthy CRAFTSMANSHIP.

STEEL PIPE HAS MANY OUTSTANDING ADVANTAGES

For many years STEEL PIPE has been used for water mains—It is particularly applicable, because of its shatter-proof strength, flexibility, ductility, long lengths, lower installation costs and greater enduring capacity. With HILL-HUBBELL MODERN methods of pipe protection applied to it, it gives long service at low maintenance cost.

SMALLER THAN 2⅜" O. D. CEMENT LINED STEEL PIPE

A specially designed pipe to replace non-ferrous tubing smaller than 2⅜" O.D. is CEMENT lined steel pipe. It is prepared with the same high quality Coating-and-Wrapping as the larger dimension pipe.

HILL-HUBBELL PIPE PROTECTION MEETS A.W.W.A. 7A.6

COATING — AND — WRAPPING — AND — LINING with BITURINE AKWALINE PRIMER AND ENAMEL complies fully with A.W.W.A. Specifications 7A.6.

WATER WASTE SURVEYS AND LEAKAGE CORRECTION

By EDGAR K. WILSON, Late Chief Engineer
The Pitometer Co., Inc., New York, N. Y.

IN THE old days when water was "free" except for the labor of lugging the buckets from the well, no check on its waste was used nor was one necessary, since that labor in itself was a sufficient check; and if an individual were so ambitious as to carry unlimited supplies of water, the thriftiness of the wife would soon curb his energy when the requirements were reached for immediate uses or the available vessels were filled.

With the introduction of pumped water, however, this guard against waste in the houses was to a considerable extent relaxed, and with the installation of more modern plumbing, not only the use of water increased, but also the waste; so the water meter was devised, and the meter, where proper maintenance has been provided, has ever since been the most efficient watchdog against a careless or wilful water waste.

Again reverting to the early days, not much thought was given to the leakage from the mains, unless it came to the surface. Since many communities had no sewerage systems, the chances for the water to get away underground were far less than at present where sewer trenches and other sub-surface structures, in addition to the water trench, make easy paths for escape without showing any signs at the surface. Such leaks may and often do continue for years without discovery. Leaks do not tend to close up as time goes on—on the contrary they may become large enough to cause a serious drain on the system.

Where there is a station meter which records the continuous flow of water, a large break will be automatically recorded and means may be taken at once to discover and remedy the trouble. Smaller leaks are likely to be hidden in the daily consumption, and as they grow in size and their number is increased, the total consumption of the system gradually creeps up and up until pumping capacities are found approaching their limit and pressures under heavy draft cannot be maintained.

Benefits to Be Derived from Leak Location Work

The location and repair of leaks, therefore, benefits a water works system in several ways:

1. By conservation of the primary supply.
2. By saving treatment and pumping costs.
3. By postponing the installation of additional pumping equipment.
4. By eliminating or postponing the need for additional supply mains.
5. By eliminating the loss of head due to unnecessarily high velocities.
6. By elimination of possibilities of accidents due to undermining streets or buildings.
7. By increase of water and pressure available for fire fighting uses; also better residential pressures.
8. By decrease in the amount of water flowing into the sanitary and storm sewers.
9. By decrease in cost of handling an unnecessary amount of water in sewage treatment plants.

Other benefits may be observed in individual instances, but the above are sufficient to indicate that underground leakage is a matter of consequence, and one which should receive the attention deserved in the operation of every water works plant.

Methods of Detection and Elimination

The elimination of underground waste can be accomplished only by a thorough and painstaking survey of the entire system, *block by block*. Unless the water actually entering each block through the night hours of minimum consumption is measured, it is not possible to know certainly whether leakage exists. Such a measurement also eliminates the necessity of looking for leaks in blocks when it is shown that no flow exists which can not be accounted for as the reasonable consumption of such blocks.

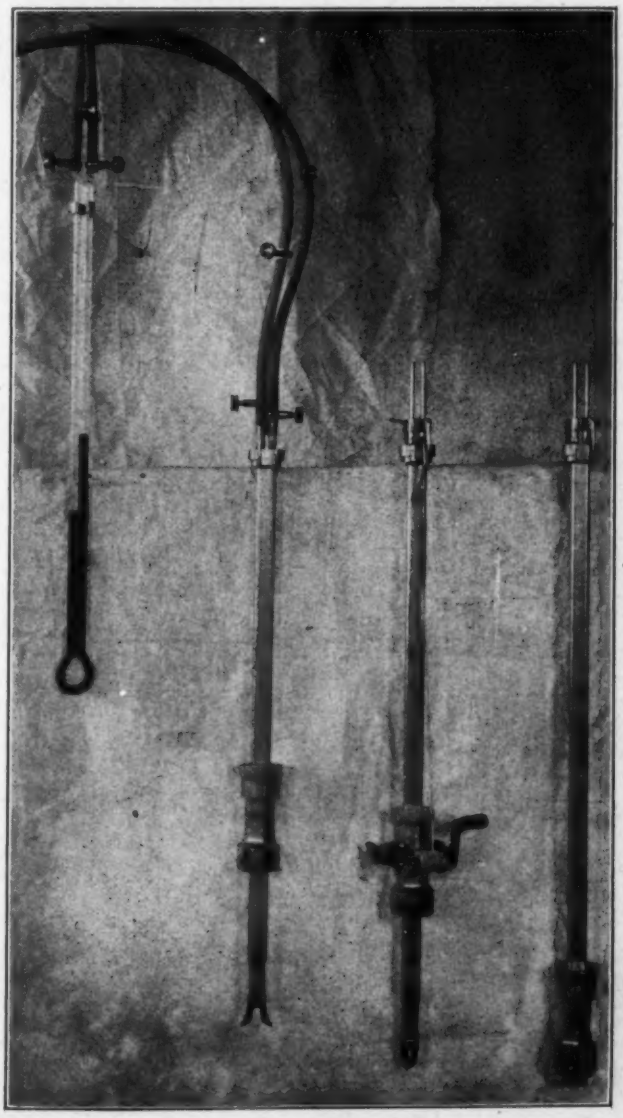
The Pitometer Survey

The best way of making these investigations is by a Pitometer water waste survey. Starting with the sources of supply or the pumping stations the survey tests the gravity supply lines for leakage, the pumps for slippage and efficiency, and the station meters for accuracy; and from that point conducts an audit of the water throughout the entire underground system.

The survey is carried on by measurements at gauging points which are installed throughout the system by inserting 1 inch corporation cocks at selected points in the mains, through which a Pitometer rod meter is introduced.

The Pitometer and Recorder

The Pitometer is an instrument based on the well known Pitot tube, adapted for the measurement of water in pipes under pressure. However, instead of having an upstream orifice facing the stream and a static orifice at right angles to the flow, the Pitometer has two identical orifices, one of which faces upstream and the other *downstream*. These orifices are connected to a glass manometer partly filled with a liquid of specific gravity higher than that of water, colored for easy observation of deflection, and also for the more effective photographing of flow records in the recorder, the description of which follows. With the apparatus entirely cleared of air, and the orifices set at the center of the pipe and aligned with the stream, a differential velocity is obtained which gives a deflection in the manometer. With the specific gravity of the indicating liquid known, the velocity and the rate of flow at the orifices can be readily determined for any given deflection observed or recorded.



Pitometer Rods and Manometer

The "Pipe Factor"

To arrive at the quantity flow accurately a "pipe factor" is required. This factor is established by what is known as "traversing" the pipe. This is accomplished by taking readings on the manometer with the orifices set at various selected points across the pipe, fairly close together near the walls, and further apart as the center is approached. These points are plotted on cross section paper and a smooth curve drawn through them. Rings of equal area, representing the complete cross section of the pipe (usually five in number), are laid down on this curve. The manometer deflection recorded at the center of each ring is taken from the curve. The sum of the square roots of these deflections divided by the square root of the deflection at the center gives the essential "Pipe Factor." This factor is nothing more than the ratio of the mean cross sectional velocity of the water flowing through a particular main to the center velocity. Then, this factor is applied to the velocity of flow obtained with the Pitometer when the orifices are at the center of the pipe.

Determining Exact Flow

The actual diameter of the pipe is measured by use of a special caliper. With the area of the pipe thus determined and the average velocity across the pipe, determined as above, the quantity of water flowing is computed.

To record the deflections of the manometer liquid over a period of time, as, for instance, twenty-four hours, the photo-recorder is used. The manometer is clamped to this instrument and by means of a lamp a record is made of the varying deflections on a sheet of photographic paper. The sheet of recording paper is carried on a clock driven drum, the speed of which is controlled by different gears, so that one revolution of the drum may take place in 12, 24, or 48 hours as desired. After the record is developed, the flow at any time during the period of the run can be determined as well as the time at which it occurred. It is evident that several of these recorders can be set up at various points to attain simultaneous flow records, without the need for having observers on the job. Furthermore, the photographic records are the most dependable sort of records.

Making the Survey

As previously stated, a Pitometer survey should start at the pumping station or source of supply, after which district measurements are made for a period of twenty-four hours throughout the entire distribution system. The districts consist of areas, selected with due consideration of pressure and flow conditions. These areas must be subject to isolation by closing all mains leading into them except one, on which the Pitometer apparatus is installed. It is not usually the case that the main feeders from the station or throughout the system can be included in any district, since the closure of such mains will almost always so affect the pressures and supply that conditions would not be normal. These feeders are therefore tested by themselves without shutting down, or possibly with shut-off of short duration only. Such shut-offs may be made during hours where no inconvenience of importance will result.

An inspection of the photographic record of the district measurement shows the relation of the total daily consumption and the important tell-tale minimum night rate of the district, which is a definite indication of the existence of waste. Since all important meters in the area under test are read during the time of flow measurement and checked for the time of minimum consumption, a correction of these amounts applied to the totals leaves the amount which must be charged to legitimate use, leakage—and, as in some cases, illicit use through unmetered connections.

With this as a basis, the district is then subdivided during the night by closing off each block in turn. Any flow which was present in the block before it was shut off will be indicated by a drop in the deflection as recorded on the photographic chart. While making shut-offs each block is tested for tightness to be sure that all valves are holding, and that there is no unrecorded connection feeding into the block. During the subdivision the time of closing each valve is recorded.

With the subdivision chart completed, the times are plotted and the result of the shutting down of each block is observed, the deflection being measured from the photographic record as on the plain manometer.

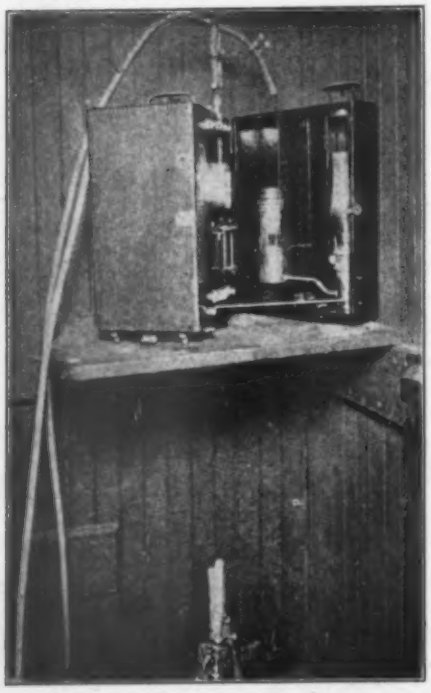
Leak Location and Meter Checking Next

The results of the subdivision are carefully studied with reference to the amount of water which may be considered to be legitimate consumption. Night rates on large meters are taken into account and investigations are made in all blocks which still appear to have an abnormal consumption. These investigations are made with various listening devices placed on service stop cocks, hydrants, on water pipes inside of houses, or on the street surface; and leaks are located so closely that it is only very rarely that more than one hole must be opened for repairs.

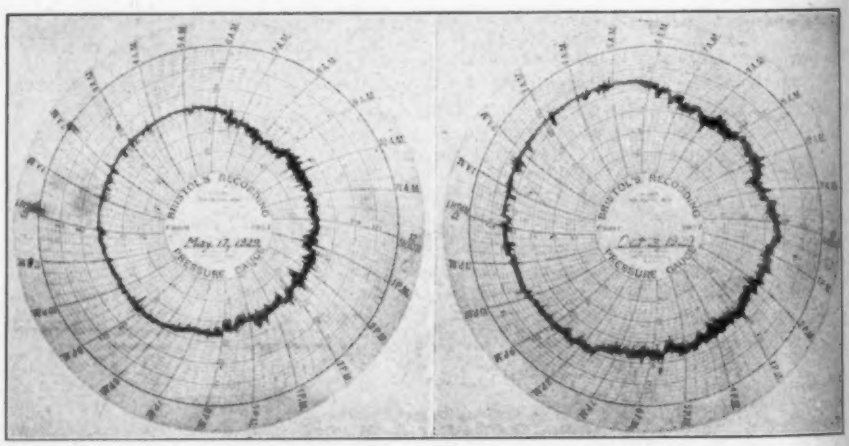
During the course of the survey large industrial meters are tested in place without disturbance, so that their actual condition previous to the test is determined. This allows the test to be carried on under the actual working conditions of the meter which is not possible if the meter is removed to the shop for testing.

Detecting Illicit Water Takings

Fire lines without meters are sometimes used for other purposes than fire extinguishing inside of manufacturing plants. While such uses, if only occasional, cannot always be detected except by long continued measurements, or by good fortune in happening to make the measurement at just the right time, if the practice is carried on at frequent intervals, the survey will furnish evidence so that back bills may be rendered for the unpaid-for water.

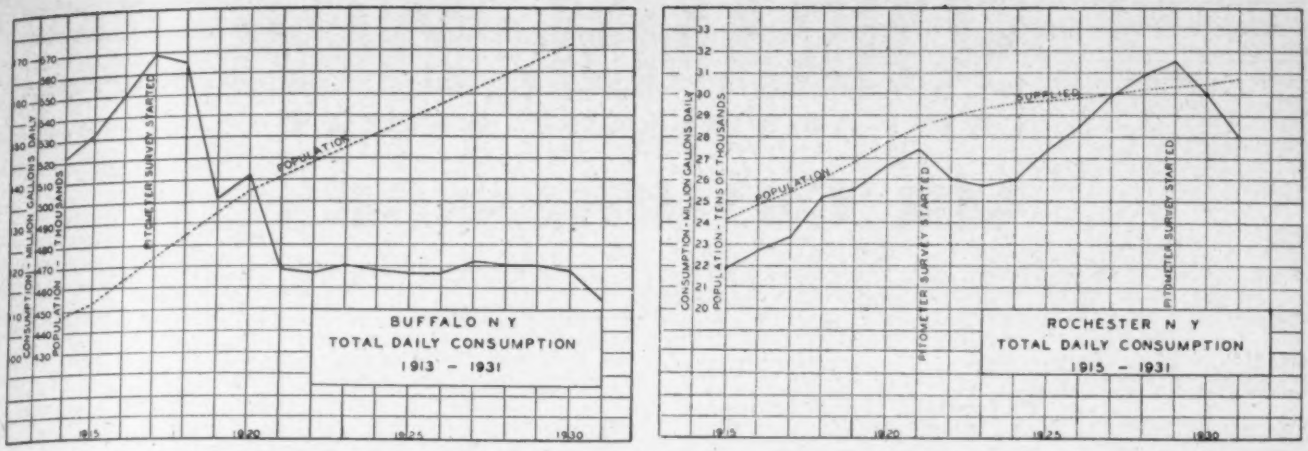


A Photo-Recorder Set-up on the Job



An Advantage of Leak Correction Illustrated

Frequently an important consideration is the recovery of pressures on the system as the result of leakage surveys and correction. These two pressure record charts (before and after), taken at an outlying point on the system, require no further explanation. Hidden in this record is that of reduced pumping costs in maintaining pressures, as well as in reduced volume pumped.



Two Rather Typical Records of Reductions in Water Pumped Following Water Waste Surveys
In the case of Rochester it is observed that following each survey the results of leakage correction and waste reduction are very evident.

At the close of the survey a report is rendered which gives all details of the survey. A list of defective valves is furnished, which is of especial value, since ordinarily about ninety per cent of the valves in the system are operated during a Pitometer survey. Suggestions are also offered in regard to locations of new valves, and other matters which make for the more efficient operation of a water works plant. One highly important consideration is that pumping efficiencies are revealed, and design deficiencies are uncovered.

The location and repair of all leaks large enough to warrant the expense of the repair brings about important reductions in the cost of water service. It is usually the case, in fact, that the cost of the survey is covered by such reduction within a few months or a year.

A leak properly repaired is permanently closed, and the loss of water is eliminated at that point. However, in water works systems leaks are forever occurring. From some the water rises to the surface; and these leaks are at once repaired; but many do not manifest themselves and again the daily pumpage increases.

A Pitometer survey must not be considered as a leak prevention undertaking. New leaks may follow the survey, but at small expense periodical remeasurements of the district will indicate where such have developed. In some of the larger cities five year programs have been instituted. These programs which cover some portions of the system each year have yielded very satisfactory results, both from the operating and economic points of view.

The Pitometer Company

Water Distribution Engineers

48 CHURCH ST. **NEW YORK, N. Y.**

Branch Offices
205 West Wacker Drive
Chicago, Ill.

THE X-RAY FOR PUBLIC WATER SYSTEMS

Branch Offices
75 State St., Albany, N. Y.
429 Penn Ave., Pittsburgh, Pa.

OFFER THREE IMPORTANT SERVICES FOR WATER SUPPLY SYSTEMS

1. WATER WASTE SURVEYS

locate hidden leaks and other sources of water waste, accounting for all the water that enters the distribution system. See Pitometer Bulletin No. 17.

2. TRUNK MAIN SURVEYS

ascertain which mains are overtaxed with resultant loss of perssure, and which mains are not doing all the work for which they were designed. See Pitometer Bulletin No. 18.

3. DISTRIBUTION SYSTEM STUDIES

determine necessary extensions and replacements to meet present needs and future requirements over a twenty-five year period. See Bulletin No. 18.

Send for Bulletins Nos. 17 and 18 — Full information on request

SCHRAMM, INC.

THE COMPRESSOR PEOPLE

AIR COMPRESSORS

Main Office and Factory - WEST CHESTER, PA., U. S. A.

SALES OFFICES AND REPRESENTATIVES

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BALTIMORE, MARYLAND.....535 E. 25th St.
BOSTON, MASS. (Newton Highlands)
.....130 Needham St.
BUFFALO, NEW YORK.....101 Great Arrow Road
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MILWAUKEE, WIS.....1123 N. Water St.
MINNEAPOLIS, MINN...514-520 Second St., S.W.
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PHOENIX, ARIZONA.....P. O. Box 3815
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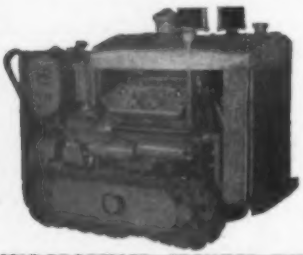
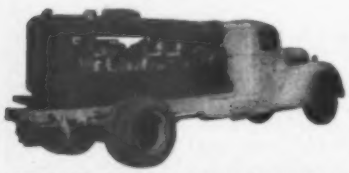
PROVIDENCE, R. I.....124 Narragansett Ave.
RICHMOND, VA.....12 N. 15th Street
SAN FRANCISCO, CALIF.....Folsom at 17th St.
SEATTLE, WASHINGTON....1520 Fourth Ave., S.
ST. LOUIS, MO.....1325 Macklind Avenue
WASHINGTON, D. C.....1254 23rd Street, N.W.

TWO WHEEL TRAILER



SELF-PROPELLED CRAWLER TYPE

DELUXE WITH TOOL BOXES AND HOSE REELS



SKIDDED FOR TRUCK MOUNTING

FULL DIESEL ENGINE POWERED

PORTABLE COMPRESSORS—All SCHRAMM Compressors are intended for heavy-duty, continuous service with minimum attention. They are suitable for service twenty-four hours per day and will perform such service with lowest up-keep and operating costs. The purpose of this page, therefore, is to present the standard types of SCHRAMM Compressors. Descriptions and data are necessarily brief but complete specifications and other information will be gladly furnished upon further request by any of the agencies listed above.

TWO WHEEL TRAILER TYPE MOUNTING: A model that can be very easily coupled to car or truck and hauled at towing speed.

SELF-PROPELLED CRAWLER TYPE: A complete No. 60 Crawler type compressor mechanically operated under its own power.

DELUXE WITH TOOL BOXES AND HOSE REELS: Provided with a universal trailer coupling or towing ring for connection to car or truck, for hauling at maximum towing speeds.

SKIDDED FOR TRUCK MOUNTING: Can be easily loaded on a motor truck body for temporary use or for transportation.

FULL DIESEL ENGINE POWERED: Cuts fuel costs and contributes to better performance and longer life.

STATIONARY COMPRESSORS: "V" OR FLAT BELT DRIVE: They can be had with "V" or flat belt pulley, or without pulley, with and without cooling unit, or base.

ON BASE WITH MOTOR: Belt drive assemblies are available for operation at standard speed or, at less than standard speed or where it is desirable to use a motor or engine of different speed.

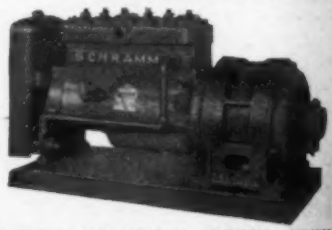
DIRECT "BUILT-IN" MOTOR DRIVE: Compressor and motor are assembled rigidly and in perfect alignment, and are mounted on a substantial steel type, closed base.

ENGINE DRIVE STATIONARY—IN-LINE—SCHRAMM Engine Driven Stationary units are made available for those applications not reached by electric power service or where gasoline, oil, distillate or diesel power units are preferred.

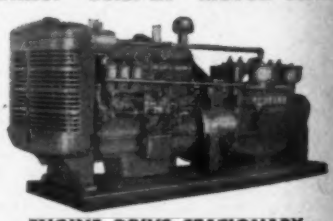
ENGINE BELT DRIVE ON BASE: Combinations of this type are assembled with compressor and power unit mounted on a steel frame, with "V" belt drive, a very compact and complete combination.

"V" BELT DRIVE

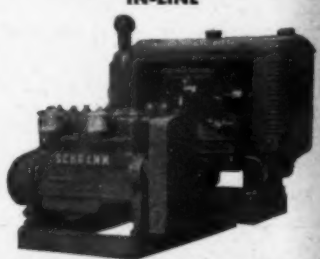
ON BASE WITH MOTOR



DIRECT "BUILT-IN" MOTOR DRIVE



ENGINE DRIVE STATIONARY IN-LINE



ON BASE WITH DIESEL ENGINE

PNEUMATIC CAULKING OF PIPE JOINTS

And Other Water Main Construction Practices

By H. WALTER HORN
Construction Engineer
Bureau of Water, Allentown, Pa.

ALLENTOWN, Pa., a city of 100,000 persons, has a municipal water supply acquired in 1869 at a cost of $98,958 when it had only 10 miles of water mains. Today, the system is valued at $6,800,000 and has 170 miles of mains.

The size of these mains is set by city ordinance and they must be laid according to specifications. In excavating, the contractor is required to hold to the line and grade established by the city engineering department. Where rock is encountered, it must be removed to a depth of 8 inches below subgrade and replaced with padding, compacted in 4-inch layers. When the subgrade is ready, bell holes are dug in advance so the pipe-layers will not be hindered. The pipe, which has been placed alongside the excavation, is rolled into position, swabbed out, and lowered into the ditch either by tripod or ropes. Particular attention is paid to the unloading of the pipe. All pipe is hauled by contract on flat bottom trucks, and removed from the trucks by skids and ropes. No pipe is allowed to be dropped or rolled from the truck.

Joint Packing

After the pipe is placed in the ditch, a single strand of square braided jute is put through the spigot end of the pipe, and the pipe is then "pushed home." If the jute is properly placed and held, it has a tendency to roll into the bell, thus reducing the amount of packing needed. Another advantage of this type of jute is that it centers the spigot in the bell, thereby reducing wedging, which would place a strain on the bell and spigot.

After the pipe is brought to grade by placing a specified 2-in. x 6-in. x 16-in. block behind the bell, the joint is ready to be packed. The jute is driven into the bell to a depth of two and seven-eighths inches, the depth of lead specified for all joints. A round runner or snake is placed in position and the joint is poured in one operation. After the runner is removed the joint is ready for caulking.

Pneumatic Caulking Adopted

A search of the literature, in 1935, for information on the subject of air-hammer caulking of lead joints between two and twelve inches failed to reveal anything, but the procedure was nevertheless adopted as standard for Allentown. It was decided that an Ingersoll-Rand No. 100 air hammer would be used as it is small and light enough to permit a man to handle it easily, while running the joint in a smooth and continuous manner. A set of caulking tools, consisting of a cutting-in chisel and six other tools of standard sizes, completed the outfit.

The first problem was to determine the amount of air pressure that could be carried without damaging the pipes. By experiment and observation the following table of pressures was chosen for the work:

Pipe Size	Max. Pressure
12-in.	65 p.s.i.
8-in.	60 p.s.i.
6-in.	55 p.s.i.
4-in. (and less)	50 p.s.i.

These pressure readings are taken at the compressor and not more than 150 ft. of air hose is used.

Any person with a little mechanical ability can acquire the knack of air-hammer caulking. In practice, every tool that fits the joint is used, beginning with the cutting-in chisel and following with each tool in successive size, from small to large, with one pass around for each. When a joint is properly caulked the lead gate will practically fall off. Figs. 1 and 2 show the caulking tools in use.

After all pipes are laid and caulked, the line is filled very slowly with water in order that the chlorine sterilizing agent (placed in every other section) will be completely dissolved. Air is expelled from the pipe at the high point during the filling process. When filled, the line is isolated and tested at 150 pounds hydrostatic head. While under this pressure the joints are carefully inspected, as a perfectly dry joint is required. If the test is satisfactory the line is flushed thoroughly and put into service.

Bedding and Backfilling

In backfilling the ditch, particular attention is paid to the bedding of the pipe. A layer of earth is placed in the ditch until even with the top of the pipe, and enough water is run in to make a good puddle. A man in boots then straddles the pipe and, moving along slowly, stamps and spades the earth until the pipe is well bedded. Following this operation several methods are used to backfill the rest of the ditch. If done by hand, enough water is used in backfilling to pack the ground well until it is within 18 inches of the top of the ditch. Dry earth is used to complete the filling after which the whole is rolled by truck.

In some instances, especially W.P.A., hand tamping was used from the top of the pipe to the top of the ditch. If the backfilling is done mechanically, a foot of earth on top of the pipe is mandatory before a bulldozer or shovel can go to work. Rock larger than a man's head may not be used in the backfill. Where there is rock formation, mechanical backfilling is not permitted. After the ditch is filled and rolled, the Water Department's work is completed. The City Highway Department makes the permanent repairs to the streets, but the cost is assumed by the Water Department.

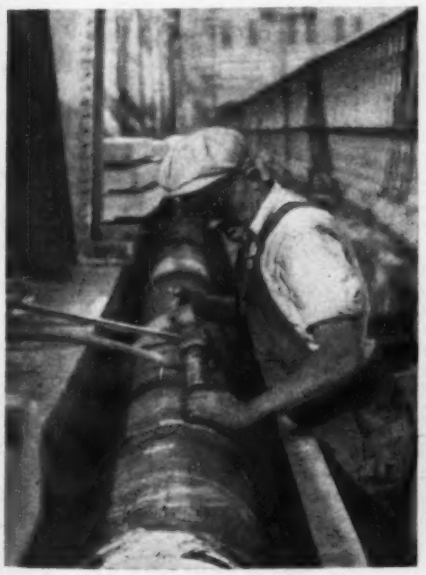


Fig. 1—Caulking a 12-In. Line on Bridge

Fig. 2—Caulking an 8-In. Line in Trench

Results From Pneumatic Caulking

Since 1935, when air-caulking was introduced into the specifications, twenty-eight miles of water mains have been laid. The success of air-hammer caulking is indicated by the fact that out of approximately fourteen thousand joints, only six 12-in. and three 8-in. had to be dug up and recaulked. Of these fourteen, three of the 12-in. joint leaks were directly attributed to an inexperienced caulker working in adverse conditions. In no instance has a fractured spigot or bell been discovered due to overcaulking. On several jobs air-caulking was permitted on two, three, and four-inch pipe. Needless to say, an experienced caulker was needed for this work.

In a recent city-wide leak survey no leaks or cracked pipes were discovered on any of the mains laid since 1935.

COMPRESSED AIR FLUSHING OF SMALL MAINS

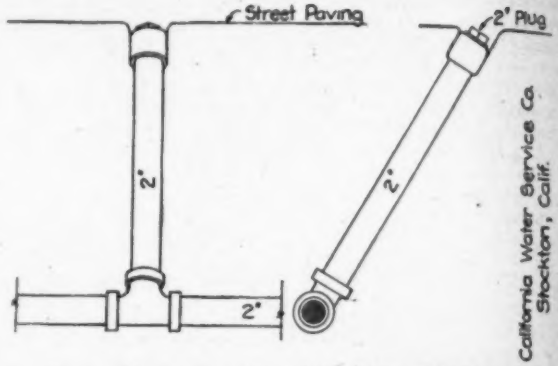
By R. F. BROWN

Plant Manager, California Water Service Co., Stockton, California

MANY water systems in the older California towns, like Topsy, just grew without any suggestion of planning for the future. Stockton was no exception. As a consequence we found ourselves with a great many 2-inch lines in the thinly populated areas.

We have for many years followed the practice of flushing small mains and all dead ends regularly by opening fire hydrants and flusher valves and simply allowing the water to flow from the main under normal pressure of 45 pounds until the main is apparently clear. Under this program all dead ends and all small mains are given ordinary flushing, approximately at intervals of every two months.

This method, however, does nothing but freshen the water in the dead ends and small mains. In order to effect a more lasting cure for taste and odor complaints, we decided to try boosting the pressure in the main with air to attempt to break loose more of the troublesome algae and other deposited material that attaches to the pipe wall. All of our dead ends, regardless of size, and at least every other block of our 2-inch lines have what we call flusher-risers installed for the convenience of our periodical flushing program—see sketch.



RISER CONNECTION TO 2" MAIN FOR FLUSHING

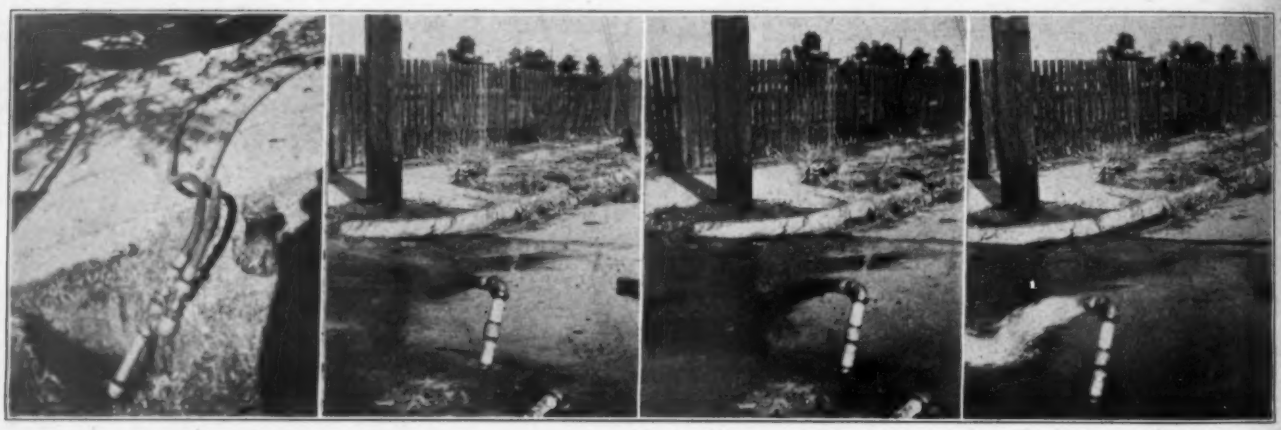
pose and it is economical, because the equipment required is only a portable air compressor and an air storage tank to provide a volume of air under pressure. No expensive cutting of mains or pavement is required and most jobs can be handled with a three-man crew.

When we first started this system we cleaned 40,000 feet of line, mostly 2-inch, over a period of two months. The cost was from 60 to 90 cts. per hundred feet, depending upon the number of services which had to be shut off and turned on again.

The success of this method of flushing is measured by the almost complete absence of the usual recurring taste and odor complaints from consumers served by mains thus treated. It is problematical how soon we will have to repeat this treatment, because from no consumer on the first line so treated has there yet developed a recurrence of complaints.

A secondary result, not anticipated, is the increase in carrying capacity of the 2-inch lines brought about by the loosening and blowing out of a great deal of scale. Thus has resulted a reduction in complaints of poor pressure as well as the taste and odor complaints.

A Self-Told Story



Air Lines Connected (This Time Through House Service at Curb Line)

First 90 Lb. Air Shot. (Note Extension Attached to Flushing-Riser)

First 45 Lb. Water Flush. (No Argument About Need to Eye or Nose)

Clear Water (Shooting and Flush Repeated As Indicated)

Air Flushing Operations

Compressed air is put into the line through a service connection midway between two flusher-risers after we have first closed the shut-off valves on the intervening services. The valve on the flusher-riser is then opened. All water in the line is forced out through the riser, by air under 90 pounds pressure. As soon as the air has expelled all the water from the line it is shut off and water under our ordinary pressure is run through the line to sweep out, through the flusher-riser, all particles of scale, sand or foreign matter that have been loosened by the air "shooting." We proceed in this manner alternately turning into the line air under 90 pounds pressure and water at 45 pounds until the flushing water leaving the risers no longer carries with it any scale or other foreign matter.

This system is apparently successful in accomplishing our pur-

COMPRESSED AIR SPEEDS PIPE CUTTING

By A. M. EDWARDS
Senior Engineer
Division of Water, Columbus, Ohio

IN COLUMBUS, Ohio, the Division of Water was faced with the problem of taking up and relaying about 4,500 lineal feet of 12-inch cast-iron pipe, made necessary by a road relocation and improvement.

It was finally decided to cut the pipe about every 42 feet, raise and remove to the new location, a distance varying from 10 to 100 feet.

Cutting operations were started by using a Strickler ratchet pipe cutter, operated from the top of the ditch, with four men working in relays of from 10 to 15 minutes. The time required for one cut on a 12-inch pipe by this method was approximately 2 hours, larger pipe required up to 3 hours.

The sledge and diamond point method was tried but it was about as slow as the cutter—and, with the added danger of cracking the pipe.

While trying to think of some means to speed up the work, the writer conceived the idea of utilizing a pneumatic wrench as a power driving unit for the Strickler cutter. This was done by assembling a gear and pinion from a horizontal gate valve, with an arm extending from the gear crank pin to the hand lever on the Strickler ratchet cutter. This assembly was bolted to the rear of a service truck, and power was furnished by a 105 cfm portable air compressor through our Ingersoll-Rand No. 58 pneumatic wrench. The latter is ordinarily used for operating large valves.

With this power assembly in place and ready to operate, the actual time for making a cut was approximately 17 minutes for a 12-inch pipe, with only one man to operate or control the apparatus. This 17 minutes compares with a cutting time of 2 hours for manual cutting, requiring four men working in relays.

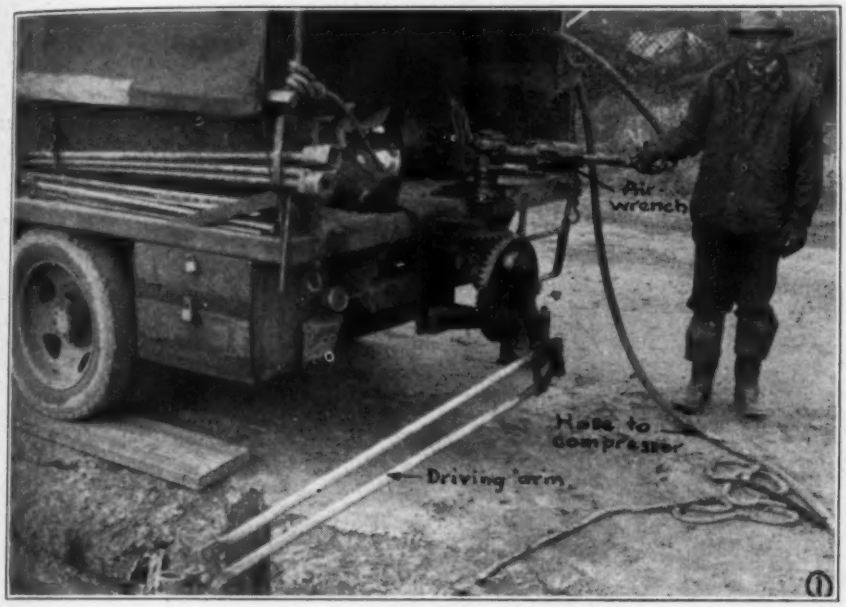
This type of cutter automatically cuts cast-iron, steel or wrought iron pipe from 1½ inches to 30 inches in diameter, either in trench or in shop.

The cutter blades make a channel cut around the pipe. The cutter assembly opens wide and is fastened by tightening one swing bolt. The ratchet head to which the hand lever is attached is equipped with dogs engaging teeth on the body of the machine which holds the star fed cutting blade. As the machine rotates around the pipe, the star feed sends the cutting tools in automatically.

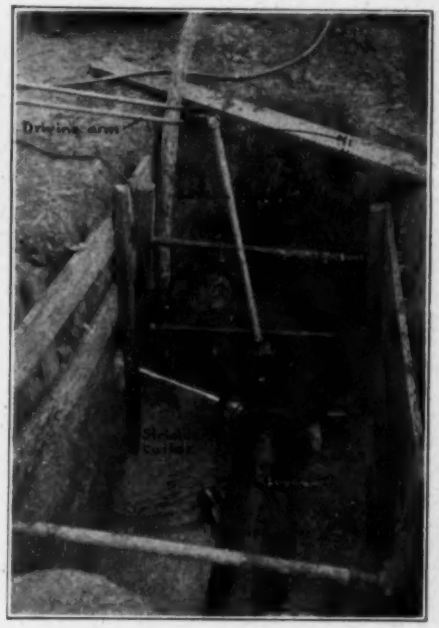
In photograph No. 1 the valve gear assembly is shown bolted to the rear of the truck, together with the driving arm and the air wrench in place, operated by one man. Ordinarily the air valve on the wrench is clamped in the open position and the wrench fastened to the truck, thus relieving the operator after the cutter has started.

In photograph No. 2, the Strickler cutter is shown in place on a 16-inch cast-iron pipe. The approximate travel of the lever is shown by the dotted line.

The particular work we were doing in the accompanying photographs was in preparation for cleaning 1,800 feet of 16-inch pipe. The pipe is Class B and the actual cutting time was 30 minutes.



1.-R. Pneumatic Wrench, Gate Valve Gear Assembly and Driving Arm



The Air Driven Strickler Pipe Cutter in Action

HOW TO BEND PIPES

TO bend steel pipes, fill with dry sand and plug the ends. Heat to a red heat in the localities to be bent and then bend. *Be sure that the sand is dry.* Where bends are slight, it is often unnecessary to use sand. The object of sand is simply to keep the sides of the pipe from collapsing, or to prevent reduction of flow area. If wet sand is used, and if the ends are plugged, the pipe may burst when heated, due to the steam pressure generated.

For the smaller pipes instead of sand resin is good. There is, however, a "right way" and possibly several wrong ways to use resin. An example of a wrong way was recently brought to my attention where the mechanic filled the pipe with resin, plugged the ends, and heated the pipe at the place where he wanted to bend it. He watched for a "red heat" just as he would had he filled the pipe with sand. The result was a violent explosion.

To use resin correctly, pour it into the pipe molten and allow it to cool and harden. As soon as the resin is hard, bend the pipe cold. Don't heat it. Then after the pipe is bent, heat the pipe all over sufficiently to melt and remove the resin.

Equal results may be secured by using lead instead of resin. I have been told that on cold days water has been used also.

Many excellent mechanical devices are on the market for bending pipe. To bend large, stiff pipe slightly (and inexpensively), there is nothing handier or more efficient, in my judgment, than a hydraulic pipe bender driven by a hand pump.

MAINTENANCE OF WATER WELLS

By N. E. GUNDERSON
President
Layne-Northern Company, Inc., Mishawaka, Ind.

IN THE matter of water well maintenance, the principal trouble encountered is shortage of water. When such a shortage occurs, it is necessary to have all of the facts regarding a particular well in order to determine the cause. There are three principal causes for shortage of water supply. First, there is always the question as to whether the ground water level has lowered and decreased the available supply of water. Second, the condition of the well itself as it affects the capacity. Third, the condition of the pumping unit.

In order to make a proper diagnosis of the condition of a well, it is necessary to compare present operation with the operation at some time in the past, preferably original operating conditions. When a new well is constructed, the owner is entitled to three definite reports. First, a well log should be kept as the well is drilled, listing each different underground formation as it is found, noting particularly where water is encountered, a point very important in rock holes. Second, a drawing of the well should be made, giving all dimensions and length of casing, screen, and shoes. Third, a complete test should be run on the well. The latter involves a determination of the static or standing water level when the well is not pumping, then the pumping level and the gallons per minute yield for a pumping period of four to eight hours, or until the water level is stabilized.

The owner is also entitled to the same complete information on the pump installation. This should include the characteristic curve on the pump, the length and size of discharge column, the length and number of stages of pump bowl, the length and diameter of suction pipe, and the length of the air line below the base plate.

Well Tests

As soon as well trouble is experienced, a test should be run to determine current operating conditions. It is also good practice to run a test of this kind periodically thereafter, since it may be possible to predict trouble from the data at hand before it occurs. The instruments needed to run a proper test are a water meter or simple orifice plate; an air line in the well, with a suitable altitude gauge at the top; and a pressure gauge on the discharge of the pump. For the test the following should be determined: the static water level and water level after starting the pump, water level after pumping several hours, gallons per minute delivery, air line reading, and pounds pressure at the pump discharge.

The static level subtracted from the pumping level gives the drawdown or distance in feet the water level recedes when the well is delivering. Dividing the gallons per minute by the drawdown gives the yield of the well in "gallons per minute per foot of drawdown." This is the specific capacity of the well and is a very important figure.

For example, if a new well had a static water level 40 feet below the surface, delivered 200 gallons per minute, and had a pumping water level 50 feet below the surface, the specific capacity was 20 gallons per minute per foot of drawdown. If the same well at a later date showed 200 gallons per minute at a 60-foot pumping level, the specific capacity is 10 gallons per foot, or only one-half of the original yield.

Static Level

If the static level is compared with the static level measured several years ago, or when the well was new, it can readily be determined whether the ground water level has lowered. Since there is often a minor seasonal fluctuation of ground water level, it is preferable to take periodic sets of readings throughout the year; or, as next best, to compare readings taken at the same time of each year.

If it is determined that the static water level in the ground has dropped to a considerable extent, the only practicable remedy is, of course, to locate a deeper formation, or to look for a new well field if the lowering has become serious. In an area where only reasonable demands are made upon the water bearing formations, however, this question is not likely to become serious, because the available rainfall in the area is ample to recharge the underground formation, except in cases of extreme demand.

Causes of Well Troubles

If the tests indicate that the specific yield of the well has been reduced to a considerable extent, the condition of the well itself should then be examined to determine the true cause of the trouble. Mechanical trouble is loose material collected in the bottom. The material may come in through a hole in the casing or screen, or under the shoe of the casing. Old wells may entirely collapse due to corrosion of the casing. If it is determined that there is no mechanical trouble in the well, it is entirely possible that chemical trouble may have developed. This chemical trouble is the deposition of salts of lime and/or iron around the screen and in the water bearing formations back some considerable distance from the screen. Originally, when rain water soaks through the ground, it carries sufficient carbon dioxide to dissolve lime and iron from the soil and from the limestone formation. Thus water often becomes saturated with carbonate of lime and iron compounds which tend to precipitate from the water on reduction in pressure, which permits the carbon dioxide gas to escape. The drop in pressure which brings on the deposition is caused by the drawdown of the well which represents the drop in pressure of the ground water required to bring the water into the well. Stalactites and stalagmites in limestone caverns are of the same material as forms in a well. The deposit which forms on all types of screen material has the appearance of grey to red putty when it is brought out of the well and examined, and usually hardens upon exposure to air. The tendency of a well water to produce this deposit seems to be based more on its stability than on its hardness. In some cases, quite hard water forms no deposit; while, in others, a water of low hardness will produce a deposit very rapidly.

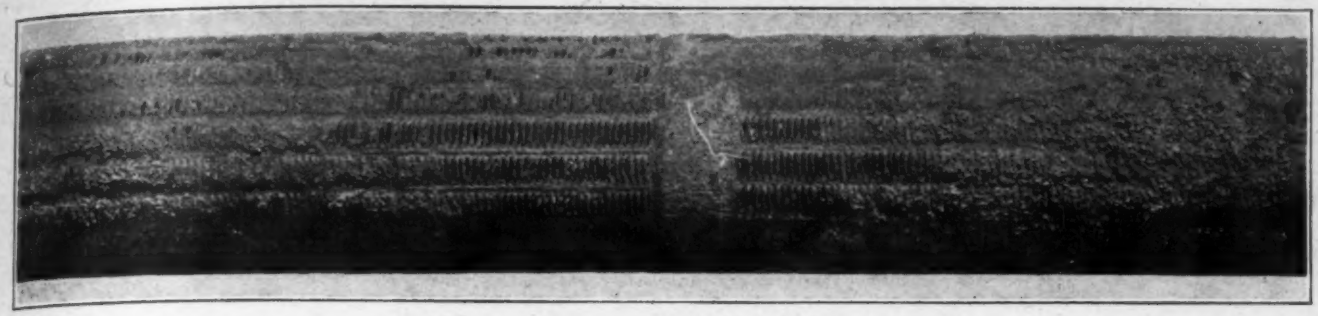
Thousand-Gallon Acid Truck
Delivering Acid Directly to Job from Bulk Station

Pump Troubles

In order to determine possible pump trouble, obtain the reading of the pump pressure gauge and convert this reading to feet. From the air line reading determine the pumping level or lift below ground. Adding the pressure in feet to the lift below ground in feet will give the total lift. Compare the gallons per minute produced at this total lift with the original pump curve and the condition of the pump can be readily determined.

If the pump is not producing the proper gallons or lift, the trouble may be caused by worn wear rings or by this same chemical deposit building up in the impellers, thus choking off the flow.

If it is found that the decrease in capacity is due to worn parts, the first step is, of course, to consult the pump manufacturer. Due to the scarcity of repair materials, it is extremely



Encrusted 18-In. Screen After Eight Years' Service
(A Job for Acid Treatment)

advisable to pull the pump on a regular schedule, possibly every two years, and check all bearings for wear. On an oil lubricated pump it is entirely practicable to reverse the shafting in order to expose a new bearing surface, and it is also possible, by adding a short section of shafting at the bottom, to move the shafting up to a new bearing surface. Every time the pump is pulled it is good practice to thoroughly clean and paint the discharge column in an effort to reduce corrosion on the surface. Only a good metal paint should be used which will adhere firmly to the surface.

When setting the pump in the well, as a precaution place a small rubber band around the pump bowl at top and bottom, particularly if the pump is finally set in the screen or in a casing only slightly larger than the pump. This rubber band can be cut from a section of inner tube. Any pump when running has a slight vibration, which in several cases is known to have actually cut through the screen or casing.

If the water is corrosive and the pump is pitting badly, it may be possible to reduce pitting by placing a small cylinder of zinc plate inside the horizontal discharge pipe next to the pump head, and another zinc cylinder inside the suction pipe just below the pump bowl. These should be riveted tightly inside the pipe, using iron rivets.

Mechanical Methods of Well Cleaning

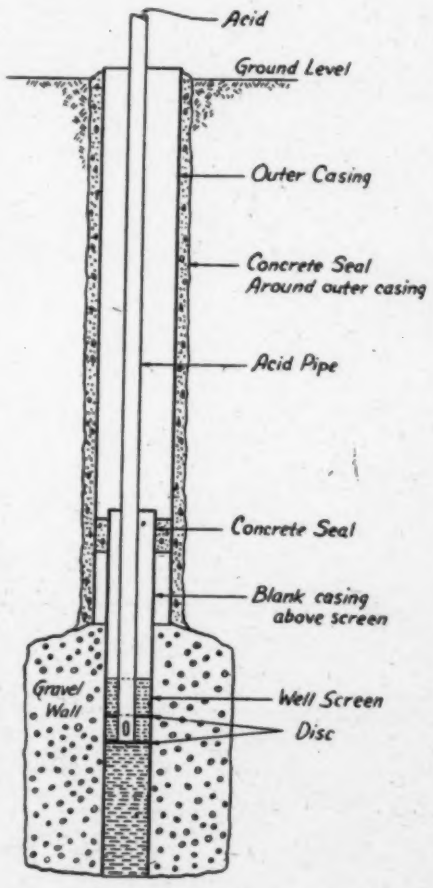
In the operation of rock wells it is quite possible for loose material to accumulate in the bottom. Such loose material may come from a hole in the casing or under the shoe. Each time the pump is removed the well depth should be carefully measured and compared with the original well depth. As explained previously, a deposit may build up in the crevices or on the wall of the rock hole. If a set of drilling tools is run in the well it is likely to brush off most of the deposit on the walls of the well. Any deposit back in the crevices can be removed only by shooting the well or by the use of acid.

If the original log indicates the depth at which the water was encountered, it is good practice to place light shots of dynamite, spaced 10 to 25 feet apart, at the points where the water was encountered, with each shot ranging from 10 to 50 pounds. The principal danger in shooting is in placing the shots too close to the bottom of the casing. A peculiar fact about shooting wells is that rupture of the casing is most likely to occur at the surface of the water. If shots are not effective in restoring the well production, the next logical step is to use acid.

The acid naturally flows into the crevices from which the water was obtained and will tend to dissolve the deposit and enlarge the crevices. After placing the acid in the well, a definite quantity of water should then be run into the top of the well to force the acid back into the crevices.

Screened wells in sand or gravel are subject to the same mechanical troubles as rock wells, such as loose material in the bottom and holes in casing or screen. The most common trouble, however, is the formation of deposits around the screen and back in the formation, as described above. The two things to remember in undertaking a cleaning job are that the deposit must be loosened and then removed. If the deposit is only loosened but not promptly removed, it will tend to settle back into place with the same clogging as before. The simplest way of loosening deposits is by running an agitator or close-fitting disc up and down in the well. This device has the disadvantage, however, that when a small section of screen has been cleaned, further use of the agitator concentrates the cleaning action on the portion of the screen already cleaned. This disadvantage of the agitator can be overcome by setting a smaller string of pipe in the well with the bottom closed, and a pair of discs on the bottom of the pipe, spaced one to two feet apart, with holes in the pipe between the discs. These discs can be set at any desired point in the screen and then the agitating effect is all concentrated at a given point on the screen.

Compressed air for cleaning is often quite effective. Air should be used with the string of inner pipe as described above, and should be piped so that by simply opening and closing a valve the air is alternately blown back into the formation or the well is pumped by air lift. This method makes it possible to loosen the deposit and remove it a few minutes later.



Method of Applying Acid to Individual Screen Sections—See Text

Another method of cleaning occasionally used is to put 500 to 1,000 pounds of dry ice into the wall and, if possible, cap the top of the well. The melting of the dry ice produces violent agitation and considerable pressure but does not remove the deposit. In some cases, backwashing a well from an outside supply of water has produced some improvement, but this method cannot be particularly recommended because it tends to wash the deposit back into the formation. A strong mechanical agitation can be obtained by piping steam down into the well where the rapid condensation provides a violent disturbance. All of the above mentioned methods of cleaning are what might be called mechanical methods, and there is also a mechanical method of preventing or reducing the formation of these deposits. When the pump is installed, if the suction on the pump is sealed tightly to the well screen, a strong backwash is provided each time the pump is stopped and the deposit is removed each time the pump is started. This seal also prevents exposing the water to the air at any time and reduces the tendency to deposit. A very simple seal can be made by building up a cone on the suction pipe made of strips of burlap saturated with tar. This cone should be placed so that it seats tightly in the top of the screen, just as the pump settles down on the base plate, so that the weight of the pump forces the seal into position.

Chemical Methods of Well Cleaning

In recent years the cleaning and developing of wells chemically, using inhibited hydrochloric acid, has been receiving more and more attention. In most cases, hydrochloric acid will dissolve a large percentage of the deposits. Failures are probably

due to the fact that the acid could not reach the deposit to work on it. The most important advance in acidizing is by the use of an inhibitor which largely reduces the action of the acid on all metals without reducing its action on the calcareous deposits. Inhibitors range from 80 to 98 per cent effective, but in this selection caution should be used to be sure the inhibitor is non-poisonous.

Another improvement in acidizing work is the use of a stabilizer. When the acid is first placed in a well it dissolves the "iron" and "lime" deposits rapidly, but as the acid becomes spent the power of the acid to hold the chemicals in solution is reduced, and there is a strong tendency for iron compounds to deposit again. The stabilizer prevents this redeposition and holds the iron in solution once it has been dissolved. In using acid it is highly desirable to heat the solution in the well. A hot acid solution acts much faster than a cold one and will also dissolve deposits which cannot be dissolved in cold acid.

There is a slow horizontal movement of ground water and in some cases cold acid has been actually carried away from a well before it could complete the job of cleaning. The fast action of hot acid makes it possible for the cleaning to be completed before the flow of underground water tends to carry the acid away.

It is also important in using acid to be sure that the acid reaches the deposit so that it can do its work. It is a mistake to simply dump acid into the top of the well. The acid should be placed through a hose line or pipe, the end of which is moved up through the length of the screen so that the acid is properly distributed. A still better way is to apply acid through the inner pipe device with two discs, as previously described, so that the acid can be delivered to any part of the screen desired. Systems have been worked out by which acid can be pumped under pressure through short sections of screen and then circulated, thus providing a washing action. Expanding devices have been used which permit application of heavy liquid pressure at selected points on the screen, which, added to the chemical effect of the hot acid, provides a very positive method of cleaning.

In using any method of acidizing, precaution should be taken to protect the men engaged in the work. The acid produces carbon dioxide gas, which comes out of the well and which cannot be detected. The work, therefore, should never be done in an unventilated pit because the workers might actually be "drowned" by carbon dioxide. In most cases the well top should be as open as possible with ample ventilation.

Following the cleaning operations the well should be flushed by pumping and the static level, pumping level, drawdown, output, and yield again determined and recorded.

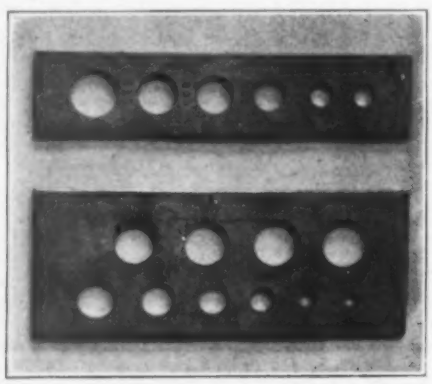
[Ed. Note: Recently some success has been had through the use of chlorine gas as a means of loosening and dissolving calcareous deposits in wells. The gas pressure serves to surge the water and the chlorine attacks the carbonate, producing carbon dioxide, hypochlorous acid and the soluble chlorides without first forming any hydrochloric acid. Hypochlorous acid is a very weak acid but will further attack the calcareous deposits.]

A GAUGE FOR METER CHANGE GEARS

By DON. C. CALDERWOOD
Engineer, Pennichuck Water Works
Nashua, N. H.

YOU may find the following gadget useful in your meter repair shop. This probably will be especially true if due to war conditions you have had to replace at least a part of your trained meter repair crew with men of less experience and ability.

Of necessity most meter repair shops carry a good stock of register and spindle change gears and regardless of make most of these gears look very much alike. Most water departments also use several different makes of meters and no matter how hard you try to keep these gears separated and in the right place they get mixed up as to size, make, and number of teeth. A trained man with a micrometer and the manufacturer's specifications can separate and properly sort out these gears, but it is a time consuming job.



Meter Change Gear Gauge

In order to facilitate this sorting, to keep our stock in order, and to assist in the meter repair work we had a set of gauges made, each gauge applying to one make of meter. A gauge consists of a piece of brass plate (nearly any metal will do) with holes drilled to the exact diameter of the change gears used in that make of meter. For example, we have several hundred "Watch Dog" meters which use change gears of the following diameters.

TABLE I
"WATCH DOG" CHANGE GEARS

Meter size	Gear Diameters—Register	Gear Diameters—Spindle
⅝"	.847"	.490"
¾"	.805"	.705"
1" & 1¼"	.522"	1.000"
1½"	1.000"	.522"
2"	.805"	.705"

Accordingly we had a gauge made with the holes of the above six diameters bored through the metal and properly stamped with the name of the meter and the diameter of each hole—see cut.

Some meters, such as the Hersey, use a slightly different system. Hersey change gears of more recent manufacture are stamped with a letter that indicates the outside diameter, but some of the older gears are not stamped or the markings are obliterated so the following table was made.

TABLE II
HERSEY CHANGE GEARS

Meter size	Model	Gear Diameters—Spindle		Gear Diameters—Register	
⅝"	F	B	.312"	X	1.008"
⅝"	D, HD, FF, HF	E	.394"	V	.937"
¾"	F	K	.541"	W	.979"
¾"	D, HD, FF, HF	P	.703"	S	.815"
1"	F, D	S	.815"	P	.703"
1"	FF, HF, HD	U	.875"	N	.645"
1¼"	D	U	.875"	N	.645"
1½"	F, D, HD	E	.394"	Z	1.125"
2"	D, HD	K	.541"	W	.979"

In this case we took another piece of metal and bored eleven holes to exact size and stamped not only the diameter of the hole but also the letter indicating the diameter.

These are merely two examples of how this problem can be handled. It goes without saying that you should limit your gauges and diameter of the holes so that they apply only to the make, size and model of the meters you are using. The information and data concerning the diameter of the change gears is probably in your files but should the information be lacking, the manufacturer will gladly supply you with it.

In making up your tables of diameter combinations for the various sizes and makes of meters you can carry it to any degree of refinement you wish. Originally our tables consisted only of the diameters of the gears and the combinations as listed in this article but more recently we have revised it to include the usual number of teeth on each gear to obtain the correct registration and the various number of teeth obtainable in a gear of any given diameter.

Like many new things the older employees rather laughed at the need of such a set of gauges, but now they freely admit that it speeds up the repair work and is a vast improvement over the old system.

In regards to the gauges themselves they are not hard to make, but we were fortunate in that they were obtained at no cost to us. There is a local school training men for jobs in defense plants and the instructor of machine shop was glad to have one of his pupils do this work as part of his training. The purpose of this article is only to give you the general idea so that you can change and adapt it to fit your own needs.

METERING: PRACTICAL METHODS OF PROCEDURE*

By E. H. RUEHL†
Richmond, Va.

"TO METER or not to meter?" That is the question. Those who have gone through the problem of making initial installation of water meters know what significance these few words can have and what discussions can be caused thereby.

However, metered water service is being acknowledged more and more as being the best all-round method of distributing the indispensable commodity, water. This is especially true since the unprecedented drought of 1930, and I am sure that if more communities were metered at that time the effects of the drought would have been less severe due to the lessened wastage of water.

Why Services Should Be Meteerd

There are many good reasons why water services should be metered, a few of which are:

1. It is the fairest way of selling water, as all customers pay in proportion to their respective consumptions.

2. The water department or company has a pretty good check on the amount of water sold and by comparison with readings of a master meter can better establish losses and leakage and thereby reduce waste in the system in general.

3. Leaks in consumers' service lines can better be located.

4. Knowledge of the various water consumptions is essential in establishing equitable water rates, and the only way in which this information can be obtained and analyzed is by metering of all services.

In some cases, especially in the municipally owned plants, there are certain institutions, such as schools, hospitals and the like, that are supplied with water without charge, and these should be metered and read regularly to get the full benefits of 100 per cent metering.

And here let me digress a little to state that the words "municipally owned" are generally a misnomer, as in the majority of cases the municipality has a large obligation in the form of outstanding bonds, and the only part that is really municipally owned is the amount covered by bonds purchased back, or some such similar item. This is mentioned here because in the municipally operated plants we are so often confronted with the statement that the people own the plant and for this reason they should have all the water wanted for some flat rate that is nowhere commensurate with the cost of producing the water, the fixed charges being lost sight of entirely.

5. It has been proven that as meters are installed that consumers' wastes have been reduced and this in turn effects economies in the amount of power required to pump, if it be a pumping plant, and in treatment costs, which are getting higher and higher every day.

6. As the water requirements of the city are kept within bounds and more or less controlled, the size of the treating and pumping plants and storage and distribution systems are kept to a minimum, thereby keeping capital investment to a minimum, as well as the necessary interest and sinking fund charges, which all result in keeping of the water rates at the lowest possible figure.

7. As the time will most likely come when sewage treatment will become necessary in a good many places, the lowering of the water losses and wastes will redound to the town's advantage in requiring a plant of smaller capacity than would be necessary if water usage and wastage were uncontrolled. Likewise, sewage pumping costs will be less.

With all these reasons in favor of metering, the only ones against it are generally found to be caused by the selfish motives wherein certain customers may want to use unlimited quantities of water without paying a just price therefor. This can be overcome in a great many cases by explanation, and, in spite of the fact that many may be adamant at first, good results are usually obtained.

Another argument against metering is sometimes set forth in that it is claimed that sanitary conditions will not be maintained if water usage be curtailed due to the installation of meters, but it has been shown that for all purposes about 25 gallons per capita per day is all that is absolutely necessary. Under any ordinary rate the cost for this requirement for the average family for an entire month would be modest, in most cases less than the cost of one filling of the gasoline tank of the automobile.

It can therefore be seen that metering is beneficial to both the municipal plant or privately owned company as well as to the consumer, since it contributes a means of compiling equitable rates and keeping bills to a minimum.

Ownership and Location of Meters

Since the type of meter and location of meter setting is governed to some extent by geographical location and local conditions, the remarks that are to follow must of necessity be confined more or less to a particular section and will apply to Virginia.

The ownership and location of the water meter are two subjects on which divergence of opinion exists. In the writer's opinion, the meter should be owned by the water department or company (being charged to capital account) and all maintenance should be done by the owners and charged to operating costs. In Virginia the meter setting just inside the curb line offers so many advantages over other locations that these readily outweigh any disadvantages in the nature of a small additional installation cost, should this be the case. In a good many houses in this section of the country there are no basements in which to locate a meter.

Advantages of Outside Setting

The advantages of outside setting, located in the sidewalk space, are in general as follows:

1. Meter reading is greatly facilitated due to the fact that the reader never needs to wait for a response from the householder on knocking, and should the party be absent it would necessitate making another trip to get the meter reading if the meter were located inside the house. The distance the meter readers have to walk is lessened when outside settings are used, and this in turn permits more meters to be read per day.

2. The meter is always accessible to water department employees for reading, inspecting, testing and repairing.

3. The danger of the meter readers and other water department employees from attacks from vicious dogs is eliminated.

4. The chance of unauthorized persons entering the house in the guise of water works employees is greatly eliminated.

5. Chance of the meter being covered by rubbish, coal, kindling wood, etc., is done away with when the outside setting is used.

6. More accurate reading can be procured when outside settings are used because of better lighting outside than generally exists in basements, under porches or other places where meters might be set.

7. The line of separation between the water department and property owners' liability is clearly defined and there is not much chance of unauthorized connections being made behind the meter.

8. In case of necessity of cutting off the water for non-payment of bills there can be no dispute as to entering the premises if the meter and control are located at the curb line.

9. The outside setting should be in a locked box and, as it is below the ground, is not so apt to be tampered with as would a setting in a more conspicuous place not protected by a box.

10. Less danger of damage to the meter by hot water exists if set at the curb.

11. Danger from freezing is practically eliminated in a well set meter, and in case of fire in the building supplied the meter is not in danger of being destroyed.

In view of all these reasons the writer is of the opinion that the entire meter setting, including the necessary cut-off valve, should be located in the sidewalk space behind the curb line, and that the water department's or company's maintenance and obligations should stop at the customer's side of the meter.

Type of Setting

The following remarks apply to the smaller size meter up to 1-inch, and when larger sizes than this are used the condition must be studied separately and settings made to suit.

It is realized that a properly set meter, although not always the cheapest, will receive more attention in general from the

*From WATER WORKS AND SEWERAGE.
†Field consultant, Virginia League of Municipalities. Former City Manager, Bluefield, Va.

water works operatives and in turn pay higher returns to the department.

It is a good plan to set the meter in a yoke with at least a control valve at the inlet side, although some prefer valves at both the inlet and outlet sides. This does away with the customary curb stop and box.

The meter in its yoke, and with the control valve, should be set in an earthenware, concrete or iron box with sufficient clearance between the risers, if they be used, that the cold ground outside cannot cause the water in the pipes or meter to freeze. A type of box that has proven very satisfactory in our section of the country is one 18 inches in diameter and 24 inches deep, with side slots at the lower end to accommodate the varying depths of the service pipe. The latter, we feel, should be about 24 inches below the ground.

It is important that a lid be provided that fits the top of the box tightly, preferably being locked on with some kind of a locking device. If the lid is fastened on there will be no circulation of air in the box and consequently less danger from freezing. Another advantage is that if the lid is kept on tightly there is less danger of persons tampering with the meter or of pedestrians catching their feet in the hole, with a possible damage suit resulting.

It is also very important that the bottom of the box extend below the maximum frost line so that the warm air from below can rise up around the meter and risers and keep the atmosphere in the box above freezing. In extreme cases it has been found that a smaller tile pipe about 8 inches in diameter put vertically into the ground below the bottom of the regular box (to reach warmer levels) overcame freezing troubles by admitting warmth from below.

Meter Reading

In the writer's opinion, meters should be read monthly, if this is possible, as by so doing a closer touch is kept on losses and wastes, and due to the visiting of each meter every thirty days the stopped meter and other irregularities can be more effectively dealt with. In case a customer has a leak he can be notified within a reasonable time if the meters are read monthly, but if they are read, say, quarterly, the amount of leakage passed will more likely be an appreciable amount and cause some disagreeableness when an attempt is made to collect the bill.

Experiences at Bluefield, Virginia

If you will pardon personal experiences, it may be of some interest to tell how the town of Bluefield recently attacked the problem of setting 700 meters at the rate of something like 100 per week. This was carried on as follows:

A work sketch was first made up and the various kinds of equipment decided on. After the meters, yolks, boxes and covers were ordered out, some figures were made up giving the length of pipe to be cut from the service to allow for elbows, yoke, valve, etc., and the vertical distance that cover, meter, yoke and fittings required was figured and each made into a constant.

Actual installation started with several men digging holes, located from the curb boxes whenever possible, in a certain well defined section so that one foreman could keep all things going. Two men, both of whom had some previous pipe fitting experience, were formed into a "gang" and given instructions how to set the meters, and they then worked together for about a day. These men then were given a helper each and two setting "gangs" were formed and these two helpers were in turn given helpers and four setting "gangs" were formed in a few days. The work was carried through, with as many men as were necessary to prepare the holes ahead of them.

Tools Required

Each of these setting gangs of two men each was furnished with a ratchet die holder and one-half and three-quarter inch dies, a hack saw, two 10-inch Stillson wrenches, a pipe vise attached to a four-legged board, a home-made wooden straightedge, and a pair of hip boots. The men provided their own rules. The meters, yokes, boxes, covers, pipe, etc., were supplied to the location by a Ford truck. Galvanized nipples of various lengths were purchased and used wherever possible, as they could be purchased cheaper than we could buy, cut and thread the pipe.

When the hole was opened down to the service pipe the meter-setting gang (two men) came along and the first thing they did was to lay the straight-edge across the hole and measure down to the service pipe, and from this the proper "constant," referred to above, was subtracted, which gave the length of risers necessary to bring the top of the meter to the desired point below the meter box lid. If there was a standard nipple of length somewhere near this dimension it was used. If not, the helper would cut pipe to the proper length and thread it. The meter setter in the meanwhile would be cutting a piece of pipe of predetermined length out of the service line and threading the cut ends for elbows. The risers were then screwed in and the yoke and meter set, after which the box was put in the hole. By using a set of specially made hooks the box was easily adjusted around the meters and risers, and the cover put on.

Two men constituted the back filling gang and followed up all setting gangs, backfilling all holes and seeing that the lids were properly fastened.

If the existing cut-off in the service line was so that it could be used to control the water it was used, but if not the meter setter would cut and thread the pipe under pressure, which only took a very few minutes. He would screw the riser pipe with control valve on, bail out the hole, and go on without having to dig back to the main or cut the water off of a section of the town. The water lost amounted to very little.

One foreman looked after the entire job and 700 meters were set at the rate of about 100 per week.

The cost of this work complete, including tools, boots, and everything, was slightly under $19 per setting, which also included the changing of some services where it was necessary.

We believe that in a place where the services are fairly close together one foreman could handle about six meter setting gangs with the necessary hole diggers and could set about 150 meters per week, providing that everything is thoroughly planned ahead.

RENOVATING WATER METERS

Water companies, on the whole, and also several of the more progressive municipally owned water departments, have found that a little dressing up of overhauled meters before returning them to the customers' service has a desirable psychological effect on the customer. The spray gun and gilt or silver lacquer or a combination of the two is the most universally employed method of dressing up old meters after they have been overhauled and tagged "O.K." on the test bench.

Mr. La Verne Trentlage, superintendent of meters in the water department of Elgin, Ill., has evolved a scheme which goes the spray-gilting method one better in making "new" meters out of old ones. In the Elgin scheme the metal parts of the meter are given a treatment which removes the oxidized or carbonated coating from the metal and leaves the parts as metal-bright as when turned out by the manufacturer.

Cleaning and Brightening Procedure

(1) Dip meter parts for 10 minutes in *hot* Trisodium Phosphate solution (2½ lbs. or more of T.S.P. in 10 gallons of water).

(2) Remove meter parts from T.S.P. solution and rinse in *hot* water to remove the alkali.

(3) Dip the parts in Muriatic Acid solution (1 part 18 degree Muriatic Acid to 2 parts of water). Allow to remain in this acid bath for approximately 15 minutes, or longer if necessary. Remove and rinse in hot water.

(4) To brighten to original lustre, immerse in the "bright-dip" solution (1 part 38 degree Nitric Acid, 1 part 66 degree Sulphuric Acid and 1 part water, plus a handful of common salt). Leave the parts in the bright dip for 5 to 10 seconds, the length of time depending on the composition of the metal and degree of brightness desired.

(5) Remove and rinse in *boiling* water to remove acid.

(6) To keep the parts from dulling on standing, a "stabilizing-dip" (especially prepared for this purpose) has been developed by General Chemical Company). After the rinse, the parts are dipped into this solution, removed and allowed to drain and dry.

Notes of Caution: Always add acids to water and *not* water to acids when making dilutions. This will preclude over-heating and spattering of the acid. Be careful to avoid splashing of the acid when dipping the meter parts. In case acid accidentally splashes on hands or face, wash at once in clean water to avoid an acid burn. Spattered acid is also hard on clothing and shoes. Rubber aprons and gloves are good protection.

Do not use iron or steel wire for dipping meter parts. Copper or monel metal wire is satisfactory.

STREAMLINE PIPE AND FITTINGS DIVISION MUELLER BRASS CO.

Port Huron, Michigan

STREAMLINE Copper Pipe and STREAMLINE Solder Fittings for Water Service Work

In 1924 the Mueller Brass Co. originated and were the first to introduce a product then known as Mueller Copper Service Pipe and Flared Fittings. This was a distinct innovation and was conceded to be the most revolutionary contribution of the time for water service purposes.

Waterworks' engineers and superintendents prefer as soft copper pipe as possible for water service work. STREAMLINE Type K Pipe is consistently and uniformly soft. It is made from Virgin Copper Ingot consisting of at least 99.94% copper and throughout every phase of its manufacture is under rigid and constant laboratory control. From the time we started to manufacture this product in 1924, and throughout the years since, we have produced the best and softest pipe that can be made for water service work.

RUST-PROOF

STREAMLINE Copper Pipe is rust-proof and is superior to any other metal for service pipe work. Under normal conditions of soil and water, it will last for generations, and will deliver its full capacity of water free from foreign particles as clear and pure as it is in the water main.

FLEXIBLE

STREAMLINE Copper Service Pipe is exceptionally and uniformly flexible. It can be very quickly and easily bent around comparatively sharp radii without annealing or loading. It may easily be bent around obstructions encountered in the trench with a great deal less cost than would be entailed in removing the obstruction.

REASONABLE COST

Copper Pipe connected with STREAMLINE Fittings is very reasonable in cost, although naturally a little more expensive than rustable pipe. It really costs a great deal less over a period of time, because replacements are eliminated owing to the rust and clog-proof properties of STREAMLINE Type K Copper Pipe.

COUPLING
Copper to Copper

VIBRATION PROOF

STREAMLINE Copper Pipe connected with STREAMLINE Solder Fittings is free from the harmful effects of vibration. Vibration is not localized at the joints as it is with threaded or flared fittings, but is harmlessly dissipated throughout the service line.

PERMANENT

STREAMLINE Copper Service Pipe is permanent. Once installed it may practically be forgotten; it will give no future trouble. For years it will continue to give the same uninterrupted service and undiminished flow of water.

COUPLING
Copper to Iron

SETTLEMENT AND FROST ACTION

STREAMLINE Copper Service Pipe is so ductile that it will stretch enough to easily take care of any settlement of filled earth, or, in fact, anything that might impose a strain on the service line which would cause failure of rigid ferrous pipe or, at the very least, cause leakage at the threaded connections.

TEE

In the Northern States and in the Dominion of Canada, copper service pipe of our manufacture has an outstanding advantage that places it far in advance of any other service material. This advantage is its resistance to frost action. This service pipe containing water under almost any range of pressure used in water service work can be alternately frozen and thawed out for a considerable number of times without showing any effect except a slight increase in diameter.

STREAMLINE SOLDER FITTINGS

The STREAMLINE Solder Fitting is connected to the pipe by feeding solder through a feed hole in the fitting. Capillarity causes the solder to thoroughly bond the pipe to the fitting and produces an enormously strong joint. This joint is so strong that if, for instance, two ¾" sections of pipe are connected with a ¾" coupling and pulled in the Olsen Testing Machine, it requires approximately 9000 pounds per square inch before a failure occurs, and this failure is always in the pipe itself, and not in the joint. This is, of course, far beyond anything it would be required to stand under actual service.

COUPLING
Copper to Inside Thread

A copy of our catalog, fully illustrating and describing these products, together with simple instructions for connecting, will be sent upon request.

STREAMLINE Fittings are manufactured under Patents 1,770,852, 1,776,502, 1,890,998.

A SMALL METER SHOP

Room Built and Equipped for the Needs of a Department With 3200 Metered Services at Cost of $1500

By ROGER W. ESTY

Water and Sewer Board, Danvers, Mass.

THE Town of Danvers is situated in the northeastern part of Massachusetts, has a population of 15,000, and is a farming and industrial community, with considerable historical background.

The water system, started back in 1876 with some twenty miles of pipe and about 500 services, today covers 67 miles and has 3,200 metered services. Our consumption started off with about 120,000,000 gallons per year and increased to an annual consumption of 550,000,000 gallons during the 1920's. Metering, which was begun in 1922, has caused water waste and total consumption to drop some every year until now Danvers uses only about 360,000,000 gallons annually.

For years, while our consumption was decreasing and our metering was increasing, our revenue kept increasing until it became permissible to reduce our service charge 20 per cent. Later the meter rate was cut 25 per cent, and it will be necessary in the very near future to again reduce our rates.

All of this is the result of planned metering. Up to two years ago we had no meter testing room in which to test, store, and maintain our meters. Most of our meters—70 per cent—have only been in about five years, and we felt it was becoming necessary to build and equip a modern, up to date testing room to properly maintain them.

Our Compact New Meter Shop

Well, what is different with our testing room than what you may have? It may be different in one respect, and that is, we are starting off with everything new. Three years ago we were planning for a new shop building but it just didn't materialize, so the Board decided that they would build and equip an up to the minute meter room within our present shop building. For the purpose $1,500 was voted to equip it.

Outside of our commercial meters we only had about 1,000 meters from 1922 to 1934. Then we started to install a few hundred each year until we had 3,200 meters in service by 1938.

The pictures accompanying this article illustrate our present set-up which we feel meets our needs in a satisfactory and efficient manner.

The room is 21 feet 3 inches long by 11 feet wide with Homasote wallboard walls, stained hardwood floor, three windows equipped with venetian blinds and two doors. So, first of all, it is light and airy. For artificial light it is lighted by fluorescent lights.

We installed a three meter Ford testing machine and Ford's Testerate device, which regulates the testing flow in gallons per minute, a 10 cubic foot tank and 1 cubic foot tank.

In the corner of the room, between the meter testing machine and bench, we constructed a wooden washing sink, which is 3 feet 4 inches by 1 foot 8 inches by 36 inches high.

Our bench is 12 feet 4 inches and 2 feet 5 inches wide and is 3 feet high. It is constructed out of oak and is covered with a steel top. It has a meter-holder on the end over the sink, where the meters are taken apart, and a small vise is located near the same end. At the other end is a portable drill press and a portable grinding and brushing machine.

Under the bench top near the sink is a drawer for the every day tools. Then an empty space to sit before, so your legs can go comfortably under the bench. Under this section is our air line hose coming in from the garage. We find the air hose a highly important and useful part of meter shop equipment because it is very essential to have air to properly clean and dry out the disc chamber for proper fitting. Also air is useful for operating a meter for any purpose, particularly the "running in" of discs.

Storage Shelves

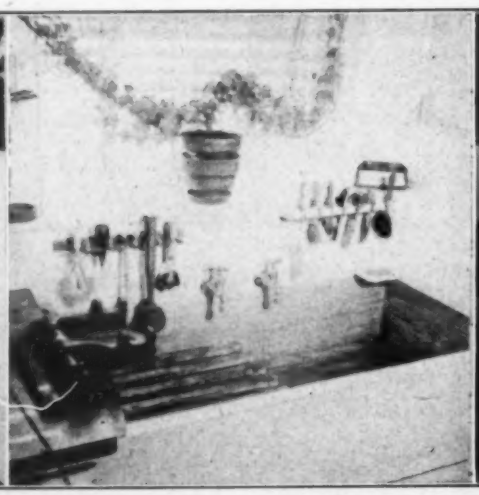
Then we have what we call our "bakers wagon shelf-storage," a series of shelves, grooved and slotted to hold gear trains, registers, covers, discs, and chambers. This is the finest method of storage that I have been able to find or devise. With this scheme many supplies can be stored in a very small space.

The next section is made up of three drawers for miscellaneous storage, equipment, and tools.

Secord File Handy in Shop

At the end of the bench is sufficient space for a steel desk which contains a card file of all of the meters. These record cards show a complete meter history as to where and when installed, when the meter has been taken out to be tested; also the results of the tests, with a list of all material used in making changes or repairs. This desk also serves as a place to do the necesary book work by the meter-man and a place to keep his test books, etc.

Along the other side of the room are three sets of steel shelving which is ample storage for all active meters. That is, those

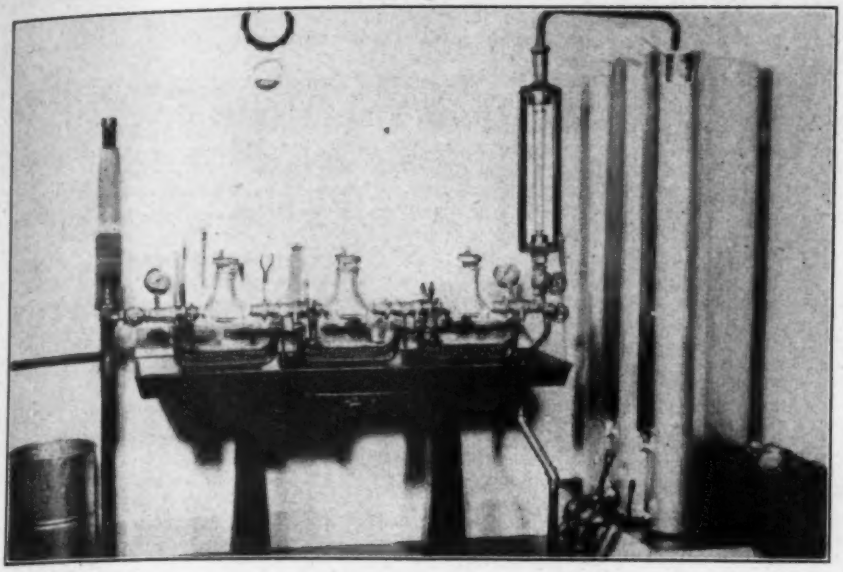


Views of the Danvers Meter Shop

Convenient method of storing meter parts. We call it our "baker's wagon," after which it was patterned.

The wash-sink in a corner; meter holder for dismantling; cleaning gadgets and handy roll of paper towels. The ivy adds a touch.

Work bench with record file and desk in corner. Portable drill press, grinding and brushing machine—and plenty of tools and light.



Our Three-Unit Ford Testing Machine
Equipped with flow indicating "Testerate" unit, above, discharging into calibrated 10 cu. ft. and 1 cu. ft. measuring tanks. This set up is a "honey."

brought back from summer service for winter storage, and from houses where service has been discontinued for an indefinite period. There are seven shelves, each supplying space to store 250 meters.

We read all of our meters by districts, as we have the town divided up into A, B and C sections, and so we have assigned Section 1 for meters in District A, and Sections 2 and 3 for Districts B and C.

All inactive meters are stored away in another room, which leaves this room entirely for active material, which plan makes for better "housekeeping."

At the end of the storage racks we have a cabinet of ten drawers, all divided up

DANVERS WATER WORKS

Make

_____ Number | Order No.

Reading B. T. | Acct. No.

_____ St. Reading A. T. | Tap No.

Date Tested

Number of Cubic Feet	Discharge G. P. M.	PRESSURE Inlet	PRESSURE Outlet	%	REMARKS

_____ 194____ _____ Inspector

Meter Test Record Form

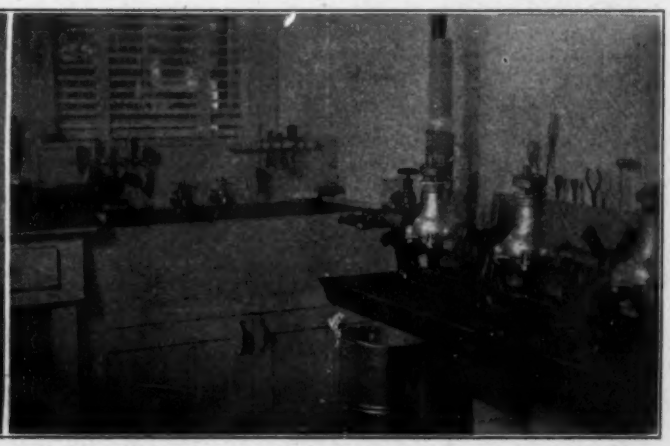
DANVERS WATER WORKS

Name .....
Address .....
Size & Make .....
Number .....
Reading .....
Date .....
Remarks .....
.....
By .....

DANVERS WATER WORKS

Name .....
Address .....
Size & Make .....
Number .....
Reading .....
Date .....
Remarks .....
.....
By .....

Meter Record Card and Stub



Two More Views
Looking "aft" down the bench. A close look will reveal the highly useful air hose at the central working space.
Another look at the "wet-end" of the room. Wash-sink, with storage beneath, and the Ford testing machine.

into small compartments, which holds the small parts of the registers, gear trains, discs, etc. Over our bench we have three sets of very small drawers, which hold several sizes of change gears and some parts of the discs and gear trains.

This description, I feel, will give a pretty good idea of what we feel a well fitted meter testing room should have, to test and maintain 3,000 meters. The only difference that I can see between what we have and a city having, say, 7,500 meters would be: first, a testing machine of greater capacity; second, a little larger bench; and third, additional storage facilities.

Design to Save Steps and Loss Motion

Make your room cozy, don't make it too barny. Arrange the testing machine, washing basin, and repair bench close together. It saves time and steps, steps—and this is very important. I have seen meter rooms in which the meter man spends far too much of his time walking back and forth and back and forth from one operation to another.

Our meter room is the result of my observations in a great many other water plants and from the many helpful suggestions we have received from superintendents and meter-men who actually do the testing. I am indeed very grateful to them, and I extend an invitation to all water works men to visit or meter room, for it may offer some thought or suggestions toward even a better set-up than we have here at Danvers.

In my travels, interviews and correspondence there seems to be no fixed standard procedure in testing, and, furthermore, no one in authority (like a sealer of weights and measures) ever checks up to see whether or not the meter has been properly and thoroughly tested to the mutual interests of the customer and the utility.

Samuel F. Newkirk of Elizabeth, N. J., is chairman of the Joint Meter Specification Committee for the A.W.W.A. and N.E.W.W.A., and his committee has essentially completed a new set of specifications that are more rigid in certain directions and more flexible in others, than those of the past.

In the August issue of WATER WORKS AND SEWERAGE there is an article on "Water Meter Maintenance Practice" that was recently read at the A.W.W.A. Toronto convention, which is very timely. It is the result of a survey by A. P. Kuranz, Superintendent of the Waukesha, Wis., Water Department, made to secure a cross-section picture of meter maintenance policies and practices in this country.

Why Not "Standards of Testing Procedure"?

The thought has occurred to this writer—why not have the present committee also develop "Standards of Meter Testing Practice," to serve as a pattern in equipping meter-test shops of various sizes, and a guide in the proper and most dependable procedures and operations in actual routine testing practice? To the writer, at the time of designing and equipping the Danvers meter-room, and to many others contemplating new meter shops or revamping existing ones, such a guide would prove of high value and usefulness. It will also go far toward bringing standardization and better practices into the important field of metering, where there appears to be room for much improvement and a real need for standardization.

ELECTRIC HEAT SOLVES PROBLEM AT PUMPING STATION

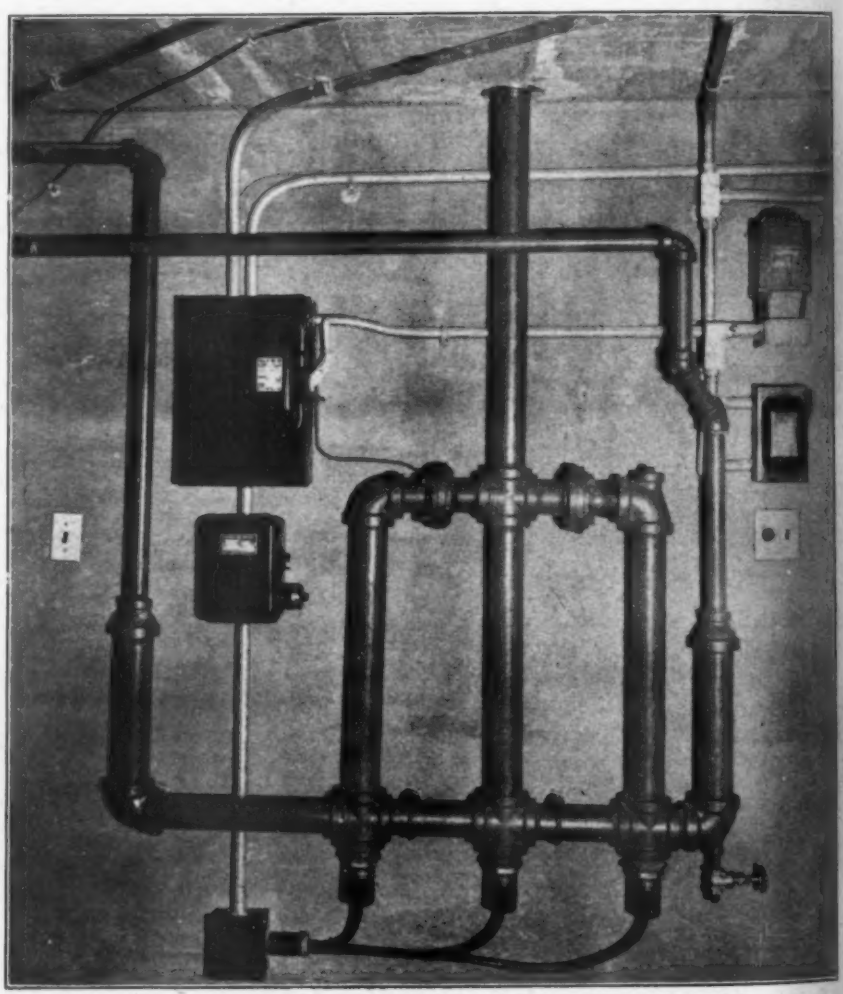
ELECTRIC heat proved the answer to a heating problem recently presented at the plant of the South Bay Consolidated Water Co. at Bayport, Long Island. This pumping station contains two rooms on the ground floor and a basement. One of the two ground floor rooms serves as an office, and the other is the chemical feeder room, separated from the first by a brick partition.

Since the chemicals stored in this second room are of a nature to attack almost any metal except cast iron, it was decided that the best method of heating the room would be by using cast-iron radiators. It was decided to build an immersion heater "electric furnace" in the basement to supply hot water to the radiators in both first floor rooms.

Three G-E electric water immersion heaters are used to heat the water in this ingenious furnace. The hot water riser leads from the top of three heater-enclosing pipes to the radiators on the main floor. The returns lead back to the bottom of the furnace, providing a neat, compact circulating system. An expansion tank is connected to each of the radiators in the first floor rooms. The radiator capacity is so arranged that the expansion tank can take care of the water expansion under any operating condition.

A magnetic contractor handles the heater load, and is controlled by a thermostat located in the operating room above.

A very clear view of this "furnace," with its electric and water connections, is shown at the right.



NOOTER

JOHN NOOTER BOILER WORKS CO.

1410 SOUTH SECOND STREET • ST. LOUIS 4, MISSOURI

TELEPHONE: GARFIELD 5338

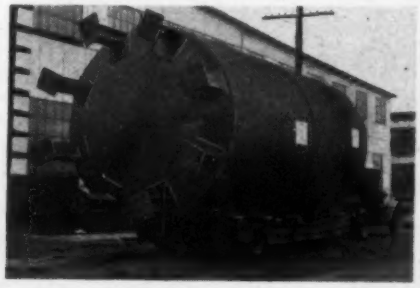
SERVICE TO WATER WORKS AND SEWERAGE DISPOSAL PLANTS

NOOTER

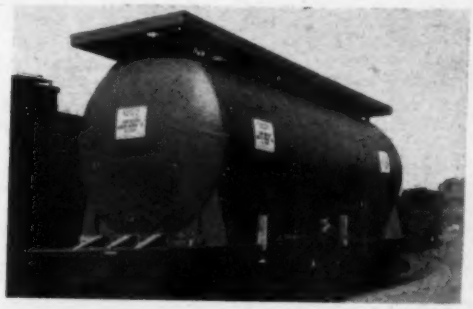
STEEL AND ALLOY PLATE FABRICATION • ASME WELDING • METAL SPRAYING • STEEL STACK FABRICATING AND ERECTING • STEEL BOILER REBUILDING • HEAVY MACHINING AND TOOLING • DIFFICULT FORMING AND PRESSING.

Track mounted flame cutting machine (lower photo) and modern planograph for precision cutting of steel (upper photo). These tools indicate the modern equipment in the Nooter plant.

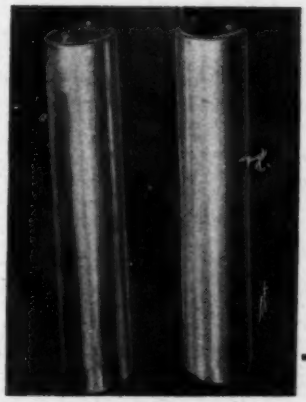
Metal spraying equipment of latest type, restoring worn bearing area.



12'-0" x 25'-6" Steel storage tank of ASME welded construction.



Large chemical mixing tank of stainless steel.



Steel storage tank protected on interior with metal sprayed zinc.

Cast iron pump plungers restored to size with sprayed stainless steel.

Lining interior of storage tank with zinc by metal spraying.

NOOTER

INFILCO INC.

Water Conditioning, Sewage Treating, Hydraulic Control and Chemical Feed Equipment

325 W. 25TH PLACE, CHICAGO 16, ILL.

PRODUCTS

ACCELATORS—Clarifying, softening and stabilizing
AERATORS—Multi-Cone, forced draft, coke tray and cascade; floating and adjustable cone aerator nozzles
BOILER FEED WATER TREATMENT PLANTS—Softener and silica removal
CARBON (Activated) PURIFIERS—Taste, odor and color removal plants
CHEMICAL FEEDERS—Dry and solution types, combination mixers and feeders
COLOR REMOVAL PLANTS
CONTROLLERS—Chemical feed, rate of flow, liquid level and hydraulic valve
DEMINERALIZATION PLANTS FOR WATER AND SUGAR
FILTERS—Concrete and wood gravity, pressure and disk type water filters; also oil removal, swimming pool, etc.
FILTER PLANT EQUIPMENT—Controls, gauges, flow meters, indicators, recorders, operating tables, transfer switches, etc.
GAUGES—Rate of flow, loss of head, liquid level, etc.
ION EXCHANGER PLANTS
LIME FEEDERS AND SLAKERS
SEWAGE TREATING EQUIPMENT—Accelo-Biox, Accelo-Filter, activators, coagulators, clarifiers, dosing siphons, rotary distributors, samplers
SOFTENING PLANTS—Lime-Soda, Hot-Flow, Accelator and Zeolite (green sand, synthetic gel, carbonaceous and resinous)
STERILIZING EQUIPMENT
SWIMMING POOL EQUIPMENT—Gravity and pressure filters, cleaners, fittings, etc.
TASTE AND ODOR REMOVAL PLANTS
VENTURI TUBES
WATER FILTERS AND FILTER PLANT EQUIPMENT
WATER SOFTENING PLANTS OF ALL TYPES
ZEOLITES AND ZEOLITE WATER SOFTENERS

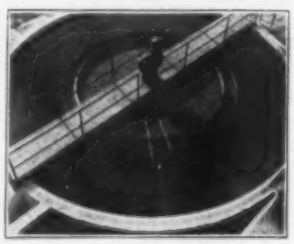
WATER CONDITIONING EQUIPMENT

INFILCO SERVICES

INFILCO has specialized in the design and manufacture of all kinds of water conditioning equipment—from Accelators to Zeolites—for over forty years.

The consulting engineer or his client can specify "Infilco" throughout the water treating plant knowing that such equipment has the benefit of Infilco's vast experience in supplying thousands of installations. Specifying one brand of equipment throughout gives the added assurance of undivided responsibility and coordinated results. The services of Infilco's staff of competent engineers and their complete laboratory facilities, ready to cooperate in making recommendations and reports, are at the disposal of the consulting engineer or his client.

ACCELATOR SOFTENERS AND CLARIFIERS

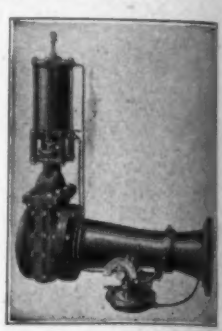


The Accelator for water softening and clarifying is one of the most important water treating developments in recent years. While retaining all of the advantages found in the conventional lime or lime-soda processes, it offers many new advantages. Treating, mixing, reaction and clarification, all are carried out in an incredibly small space. Treating chemicals are applied in a new way. Reactions occur under new conditions. Size is but a fraction of that for old type plants where design was based upon holding time requirements for chemical and physical reactions and for sedimentation.

ZEOLITES AND ZEOLITE SOFTENERS

Infilco Zeolite Softeners are of either pressure or gravity type, and are built in sizes to meet any capacity requirement. Controls are furnished for either manual, semi-automatic or full automatic operation as desired. A variety of Infilco Zeolites are available, and the selection of type to be used will depend upon the characteristics of the water to be softened and upon requirements. All Infilco Zeolites are capable of quick regeneration, considerable overload capacity and operation at high rates of flow.

CONTROLLERS AND GAUGES



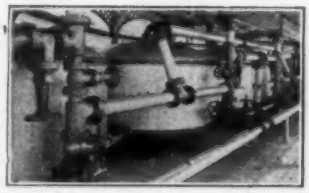
Infilco Rate of Flow Controllers, for automatically maintaining uniform rates of flow, are noted for their accuracy, low loss of head, reset and rate setter features. Infilco Water Level Controllers operate hydraulically controlled valves to maintain proper liquid levels.

Infilco Indicating and Recording Rate of Flow, Loss of Head and Liquid Level Gauges and Illuminated Indicators provide visual indication and permanent records of plant operation.

PRESSURE AND GRAVITY FILTERS

Clean, clear water, essential for municipal supply, is assured by Infilco pressure or gravity type filter plants, in capacities from a hundred gallons per day up.

The design of every Infilco filter plant is based upon sound engineering principles, backed by over four decades of experience in equipping many hundred municipal water works, and building tens of thousands of industrial filters.



RECARBONATORS

Infilco Recarbonators are available for the stabilization or recarbonation of industrial liquids, trade wastes and lime-softened water. Infilco equipment provides for the complete process of producing, cooling, scrubbing, compressing, drying and applying carbon dioxide gas to the liquid.

COAGULATORS

Infilco Coagulators promote economy and efficiency in the chemical treatment of water and sewage. The applied chemicals are fully utilized by bringing them into intimate contact with the liquid undergoing treatment. The suspended particles are collected rapidly and quickly aggregate into masses having very high subsiding values.

TRANSFER SWITCHES, OPERATING TABLES ROBOTROLS AND SAMPLING TABLES

Infilco Transfer Switches provide finger-tip control of hydraulically operated mechanisms. They meet every requirement of 4-way plugs or piston cocks without their inherent disadvantages. Extreme compactness is obtained by grouping all four separate valves in one body, along with pressure and waste passages.

Infilco Operating Tables offer both utility and a pleasing appearance. They provide centralized and simplified control for a number of hydraulically operated valves, and at the same time furnish an attractive mounting for the control levers, indicators and gauges.

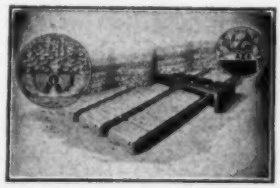
The Robotrol is a robot filter, or softener, operator. It backwashes (or regenerates) and returns the unit to service—automatically, efficiently and without supervision.

Sampling tables furnish a visual check on the condition of raw, settled and filtered water.

HYDRODARCO PURIFIERS

Hydrodarco is the activated carbon made expressly for water purification. Hydrodarco Purifiers, employing beds of granular Hydrodarco, automatically remove tastes, odors, chlorine, iron, organic color, etc. They are furnished in capacities from a few gallons per hour to millions of gallons per day.

INFILCO FILTER UNDERDRAINS



Wagner Filter Underdrains provide a primary distributing system of a manifold and laterals on wide centers, with distributing orifices along their undersides; and a secondary system of Wagner precast blocks fitting between the laterals. The system fills every requirement for perfect wash water distribution. With manifold and laterals of Transite (an asbestos and Portland cement product) this underdrain is practically everlasting.

FLUOREX PURIFIERS

Fluorex is a specially prepared, highly porous and reactive tricalcium phosphate for removing fluorine from water. Fluorex Purifiers, with their improved method of regeneration which prolongs the active life of the adsorbant and makes possible the use of ordinary materials and construction, offer the ideal means of removing fluorine.

AERATORS

To permit selection of the proper type of aerator to meet conditions of head and space available, character and quantity of water to be handled, and the results desired—Infilco offers its MultiCone, forced draft, coke tray, floating cone, adjustable cone and cascade aerators.

CHEMICAL FEEDERS AND PROPORTIONERS

Infilco Chemical Feeders—dry or solution—provide means for volumetrically or gravimetrically measuring and feeding chemicals in any form: liquid, powdered, granulated or lump. Capacities are from a fraction of a pound to hundreds of pounds per hour.

Infilco Continuous Lime Feeders and Slakers combine in one continuous, automatic process, the consecutive operations of feeding and slaking crushed or pebble quicklime, followed by the preparation and delivery of a suitable milk of lime mixture.

Infilco Proportioners maintain predetermined ratios between liquid or solid flows, or automatically vary the ratio of one flow with respect to another, by electric, hydraulic or mechanical means.

SEWAGE TREATING EQUIPMENT

INFILCO manufactures equipment for all sewage treating processes—chemical, biological and mechanical. In offering many products for application in these various processes, Infilco also offers the user the advantage of centralized responsibility, which is important in assuring continued satisfactory equipment operation.

ACCELO BIOX PROCESS

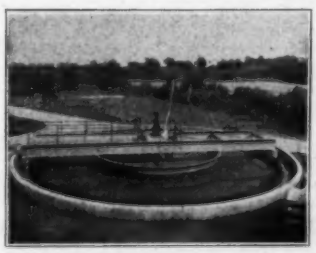
Accelo Biox is Infilco's name for a high rate activated sludge process involving direct recirculation of aeration tank mixed liquor. This process is producing results comparable to those obtained in any conventional activated sludge plant and it employs only half the aeration tank volume and blower capacity. The resulting savings in initial investment and operating cost are readily apparent. Designs embodying the Accelo Biox Process are available for any sized plant.

ACCELO-FILTER SYSTEMS

The Accelo-Filter system provides a new and improved method for treating sewage and organic wastes by constant, *direct* recirculation through the trickling filter. This results in repeated inoculation with freshly aerated material and provides effective reduction of the organic content of the biological filter at a considerably higher dosage rate.

Aero-Spray Nozzles on a rotary distributor (above) provide a fan-shaped variable spray which assures optimum coverage and maximum aeration in the application of screened, settled sewage to trickling filters. All parts of these improved nozzles are bronze to assure long life.

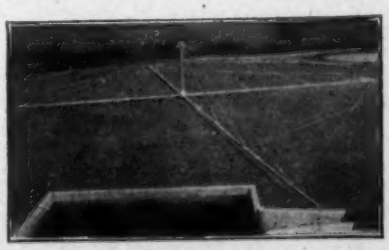
CLARIFIERS



Infilco Types WS and PD Clarifiers obtain a perfect balance of the conditions necessary for efficient operation of a sewage concentrator. These Clarifiers are designed with curved rotating scraper blades that gently concentrate and remove settled material with practically no disturbance of the liquid. Accordingly, retention periods may be selected to avoid both septic action and excessive surface scum formation.

The two different sizes of Infilco Clarifiers assure effective removal of solids from the sedimentation tank whether it be small or large. The WS Clarifier with central motor reducer drive is supplied for tank diameters up to 40 feet. For diameters larger than 40 feet, there is the PD Clarifier, driven by a horizontal motorized reducer through a pinion which meshes with a stationary rack at the tank periphery.

ROTARY DISTRIBUTORS AND DOSING SIPHONS



Only Infilco Rotary Distributors offer so many important refinements such as full-opening arm end gates, mercury seal with protective seal ring, and corrosion-resistant nickel iron castings, along with low operating head requirements and uniformity of distribution. Infilco dosing siphons insure perfect operation of distribution mechanism at all flow rates.

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"CHEMICAL FEEDER HEADQUARTERS"

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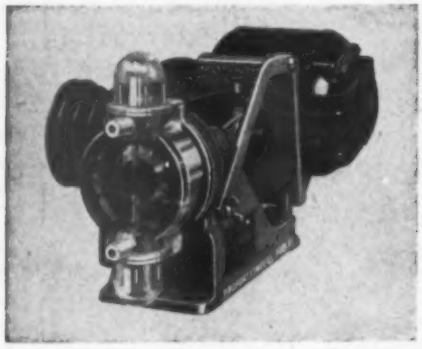
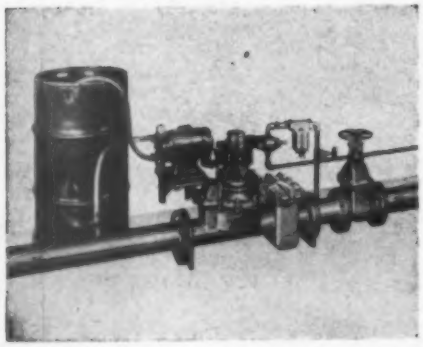
PRODUCTS — Single or Multiple Chemical Feeders for water and sewage plants, the military, and industry; and engineering service on proportioning problems. Feeders are of positive-displacement solution-feed type. For constant rate or proportional feed with mechanical or hydraulic operation. Chemical solutions handled with "See-Thru" transparent plastic reagent end construction include: Sodium or calcium hypo-chlorite, aqua ammonia, soda ash, alum, ferric chloride, ferric sulphate, calgon, sodium aluminate, copper sulphate, sodium hydroxide, dilute acids, etc. Other construction for concentrated Sulphuric acid and hard to handle chemicals.



Chlor-O-Feeders in Water Works Service for Sterilization (Hypo-Chlorinators)—Midget Chlor-O-Feeders (diaphragm or piston type for low or high pressures) for pumped water supplies are the most dependable and least expensive, most accurate and least complicated feeders available for chlorination of up to 1½ million gallons per day. The Chlor-O-Feeder is small, easily and quickly adjustable to various feeding rates; driven by electric motors or belt driven from water pump. Installation is simple with aid of our complete instruction manual.



Proportional Chlor-O-Feeders for Gravity Water Systems — For many conditions, especially in gravity systems from reservoirs, where flow rates vary considerably from hour to hour, it is essential that the Chlor-O-Feeder be controlled by the flow of water so that the amount of solution injected is at all times in proportion. Proportional Chlor-O-Feeder can be mounted on and controlled by any flow-responsive device, standard water meter of any size or type; flow-responsive rotor; Venturi tube; orifice plate or even the reciprocating parts of deep-well pumps can be used to "pull the trigger" that sets off the chlorinating discharge. This Chlor-O-Feeder can be operated at any point where the water line can be cut to allow installation of meter. It can be operated entirely by water pressure, so does not require expense of wiring. Operation is simple, not needing expert attendants.

Calgon Feeding and pH Control—pH control by proportioning lime, soda ash, sodium silicate, sulphuric or other acids, is made simple by the use of these flow-proportional chemical feeders. Highly successful installations, designed by leading engineers, are providing permanent relief from plugged and corroded pipe lines. The growing use of Calgon in water works corrosion control finds frequent use of Calgon-Feeder for feeding sodium hexametaphosphate.

OMEGA MACHINE COMPANY

A DIVISION OF BUILDERS IRON FOUNDRY

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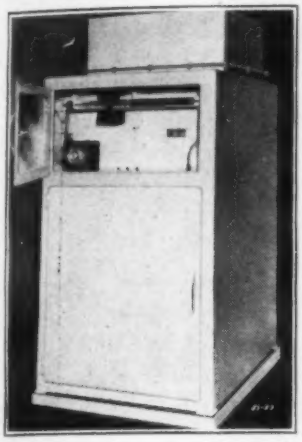
EQUIPMENT

For Dry Material	For Liquids
Loss-In-Weight Type Gravimetric Feeders	Precision Feeders
Belt Type Gravimetric Feeders	Rotodip Feeders
Weighcheck Feeders	Laboratory Stirrers
Universal Volumetric Feeders	Lime Slakers
Disk Feeders	Mixing and Coagulating Equipment
Dust Removers and Filters	
Combined Bucket Elevators and Feeders	Automatic Proportional Control Equipment

GRAVIMETRIC FEEDER "LOSS-IN WEIGHT" TYPE

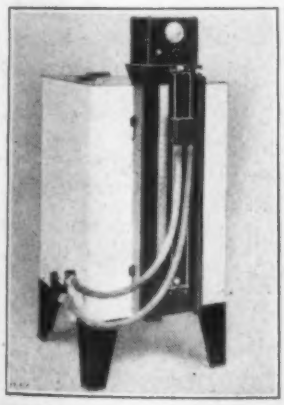


This is without a doubt the most accurate type chemical feeder made. Indicates the weight of material in the hopper at all times on the scale beam. Feeds lump, granular or powdered materials at 100 different rates by increments of 1% of the maximum rate of feed. No calibration is required. The rate of feed is automatically controlled by the loss in weight in the hopper of material. Records every pound of material delivered by the feeder on a mechanical counter geared to the lead screw which retracts the counterpoise. The size No. 1 feeder illustrated feeds up to 2000 pounds per hour.

BELT TYPE GRAVIMETRIC FEEDER AND SLAKER

"OMEGA Continuous Lime Feeders and Slakers" are available in sizes from 175 to 10,000 pounds per hour. Feeder illustrated weighs the lime on a short 20" conveyor belt which is carried on accurate, sensitive scales. Slaker is an insulated multi-compartment type and equipped with heat exchanger coils for high temperature efficient operation. Water jet operated dust and vapor removal devices prevent clogging of the feeding mechanism. Clinker removal is easily accomplished without shutting down.

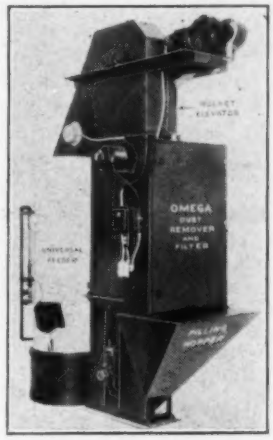
PRECISION FEEDER



Not an orifice feeder but a true Volumetric feeder of the most accurate type for feeding solutions of Calgon, Hypochlorite, Copper-Sulfate, Ammonium Sulphate, etc. Feeding range from 1/25 to 400 gallons per hour. For any feeder the range is 100 to 1. Standard tank sizes, 15, 25, 50, 100, 200 or 400 gallons. Feeding mechanisms can be furnished for customer's tanks. Where electricity is not available, eight-day spring motors are used.

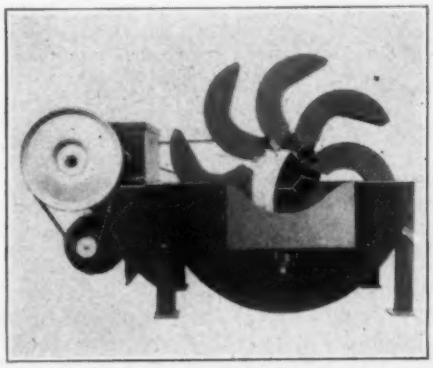
UNIVERSAL FEEDER...ELEVATOR AND DUST FILTER

The illustration shows a Universal Feeder with lead lined dissolving chamber, stainless steel, high speed mixer and Rotameter on water supply. These accessories recommended for feeding Ferrisul, Ferrifloc and low grade alum. Included also is a bucket elevator for use where overhead storage is not available. Note low and high level controls on feeder and elevator housings. Dust remover makes hopper charging a completely dustless operation. Complete chemical feeding systems are engineered and built to fit the job.



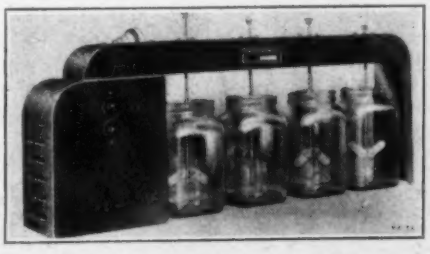
ROTODIP METER

For feeding from large supply tanks which may be located at a distance from the feeder. This cut-away view shows the metering wheel discharging into the receiving box at a high rate. Feeding range 1 to 800 gallons per hour. Variable speed drive gives an infinite number of speed changes from zero to maximum. Liquid feeders and dry feeders may be accurately synchronized to make up fixed strength solutions or suspensions.



LABORATORY STIRRER

For jar tests to determine proper coagulant or carbon dosages. Also ball mill or tumbler type for agitating material in closed vessels for threshold treatment tests.



WALLACE & TIERNAN
COMPANY, INC.

Manufacturers of Chlorine and Ammonia Control Apparatus

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"The Only Safe Water Is a Sterilized Water"

CHLORINATION FOR SAFETY

Chlorine treatment of drinking water is universally recognized as the most effective protection against waterborne disease bacteria. 94% of the total amount of water plant output in the United States is chlorinated.

The chlorination of a public water supply is a responsibility that calls for the employment of both the best equipment and engineering advice obtainable. In furnishing chlorinators for any water supply, W&T engineers give the benefit of their wide experience in dealing with every kind of water purification problem.

W&T DRY CHEMICAL FEEDERS

For the application of dry chemicals in water works and sewage plants dry feeding has proved to be definitely superior to wet or solution methods. Wallace & Tiernan furnish several types of dry chemical feeders for uniform wide-range feeding of such dry chemicals as alum, lime, soda ash, carbon, etc.

W&T CHLORINATORS & AMMONIATORS

For water works systems the visible vacuum principle of chlorinator design is the recognized standard of excellence, thoroughly tested through years of successful field operation.

W&T Visible Vacuum Chlorinators furnish closely controlled solution feed over a wide capacity range, with either manual or automatic regulation of the application rate. Pressure type Chlorinators are also available.

Accurate control is as important in the application of ammonia as of chlorine, and W&T Ammoniators provide the necessary accuracy and dependability in operation.

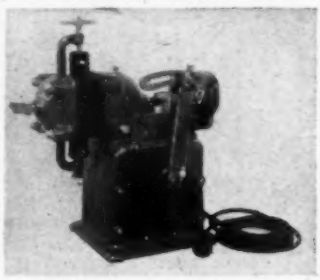
W&T "Visible Vacuum" Chlorinator for automatic proportioning of chlorine to the flow of water. A companion unit with manual control is also available.

THE W&T CHLORINATION TRAILER

For emergency use, and for secondary chlorination requirements, the W&T Chlorination Trailer is especially valuable. It also is suitable for chlorination treatment of new main extensions before they are opened to service, and for any secondary chlorination at a distance from the water plant.

THE W&T HYPOCHLORINATOR

Chlorination of the small water supply, either public or private, where chlorine requirements are small and supervision is limited, presents a distinct problem, which the W&T Hypochlorinator is specifically designed to meet.



W&T Hypochlorinator for treatment of small water supplies is economical and simple to operate.

Small, easily installed, and needing a minimum of operating supervision, it gives efficient protection to the small water supply at the lowest possible cost.

TASTE AND ODOR CONTROL

Next to insuring that a water is safe to drink, it is important that it be palatable and free from odors. Disagreeable tastes and unpleasant odors arise from various causes, such as algae growths, or the presence in the water of industrial wastes, particularly phenols.

Modern water treatment methods, such as "Break-Point" Chlorination and Chloramine (chlorine and ammonia) Treatment, provides a water that is both palatable and thoroughly safe.

W&T MOF Dry Chemical Feeder provides wide-range feed of various powdered chemicals.

W&T TECHNICAL SERVICE

For any water treatment problem W&T Representatives will gladly furnish technical assistance and make practical recommendations, without obligation.

CONTROL OF MICRO-ORGANISMS AND AQUATIC VEGETATION

By L. F. WARRICK*
H. E. Wirth and W. Van Horn
Madison, Wisconsin

PUBLIC interest in clean waters has manifested itself in many ways in recent years. Pollution control agencies have been established in many states, and every session of Congress for the past decade has been called upon to consider legislation relating to this subject. Stream clean-up programs have been inaugurated. In rapidly increasing numbers municipalities have installed modern sewage treatment works. Industries have either proceeded or are being induced to develop and install methods for utilization or treatment and inoffensive disposal of pollutional wastes. The objective of all these efforts is to restore polluted water courses to proper sanitary conditions and to keep them as clean and attractive as possible.

The purpose in discussing the control of aquatic nuisances by chemical methods is to present another phase of the general problem of keeping waters clean and attractive, aside from treatment of sewage and trade wastes. The intent is to set forth, briefly, difficulties created by superabundant growths of algae, rooted weeds and certain obnoxious growths in lakes and streams, and to follow with a review of developments in overcoming some of these difficulties.

Algae may be popularly described as microscopic, one-celled plants produced in immense quantities in shallow water areas under favorable seasonal conditions. Growing in reservoirs, they achieve notoriety as the cause of nauseating tastes and odors in drinking water. The effectiveness of copper sulphate in suppression of algae growths has long been known, but there are certain important considerations involved which must be met in large-scale applications of such treatment to assure satisfactory results. It is also proposed to describe some of the studies that have been carried out under the general supervision of the Wisconsin Committee on Water Pollution through its Committee on Chemical Treatment of Lakes and Streams, with attention being called to methods for more definitely controlling dosages of chemical to prevent unnecessary damage to fish and other aquatic life, particularly fish foods.

General Problems

Under certain conditions, not well understood at present, algae multiply so rapidly that in a number of lakes and streams their presence gives the water a pea-soup color and consistency. These algae "blooms" naturally detract from the enjoyment of the waters by cottagers, bathers, boaters and fishermen because of the stench produced during the decomposition of such masses of algae. Similarly, many weed beds, heretofore ignored or regarded as desirable for the maintenance of good fish population, have become a nuisance and hindrance to the more popular recreational uses of lakes and the development of residential areas or summer resorts around bodies of water.

Rooted plants growing in abundance in recreational areas have caused much trouble for resort and other property owners. No one enjoys using a beach populated by a dense growth of weeds. Boating is difficult when weeds become wrapped around oars or propeller. Offensive odors result when the plants decompose after they have been cut and washed ashore, or have died in the fall.

One of the Smaller Outfits for Copper Sulphate Spraying of Small Lakes

Some people are allergic to aquatic plants and develop rashes when they swim in certain weedy areas. Another problem, closely allied to allergy, is caused by a microorganism (*cercariae*), the effects of which are commonly referred to as "swimmer's itch." Outbreaks occurring in some bathing areas have annoyed and alarmed persons both directly and indirectly affected.

There is also an economic aspect that must be considered. The decreasing value of real estate bordering infested lakes is a direct loss to owners and eventually may have a serious effect on tax rolls. Industrial processes have been interfered with at times by algae growths, which have hampered production or caused loss through spoiling the product. For instance, paper mills have had objectionable odors imparted to paper and boxboard used for packaging foods and confections by large amounts of algae growing in the water supply used by the mills. There are instances on record where the death of cattle and other livestock has been attributed to the presence of algae in the drinking water. All of these conditions have resulted in efforts by property owners and others concerned to control these algae, weed and other growths considered aquatic nuisances.

One-Man-Power Barge
Applying copper-sulphate treatment to a shallow waterway to control odors from algae growth.
"Stern-Wheeler"

Control Measures

Efforts to eliminate unwanted vegetation have generally utilized manual or mechanical methods. Under-water cutting machines have been made available for cutting rooted weeds. The manually-operated equipment consists of a ribbon steel saw which can be drawn back and forth across weedy areas in the manner of a lumberjack's saw. Power cutters mounted on barges, patterned after harvesting machinery, have been developed. Tractor or truck drawn cables have been used to remove littoral vegetation. (See WATER WORKS AND SEWERAGE for March, 1942—"The Control of Water Chestnut Growths.") Cut material must be collected and removed for burning, burial or disposal on land at isolated places. Otherwise, it will drift to shore, decompose and cause an odor nuisance. Dredging generally effects more lasting results than weed cutting because of removal of the roots.

At best, all of these are laborious, time-consuming methods. They are effective in solving only a part of the general problem of aquatic nuisance control. They do not take care of troubles caused by excessive growths of algae or small free-floating plants.

Early Studies:

Investigations of chemical treatment were started at an early date to devise practical procedure for taking care of all phases

*Chief Engineer, Assistant Sanitary Engineer (now Lieutenant with the Armed Forces) and Assistant Biologist, respectively, of the Wisconsin State Department of Health.

of the problem. Tastes and odors in water supplies having been identified with growths of algae more than sixty years ago, attempts were first directed to overcoming this difficulty. Studies were undertaken by the Bureau of Plant Industry, U. S. Department of Agriculture, in cooperation with the Massachusetts State Board of Health, and in 1901 Moore[3] successfully worked out a procedure for destroying algae with small quantities of copper sulphate. Further studies of the application of this method were reported in 1904 by Caird[2] at Elmira, N. Y., Carroll[3] at Butte,

This barge, for the control of both algae and rooted weeds, is used by a Sanitary District set up by a Wisconsin town for the primary purpose of applying preventive treatment in the control of aquatic nuisances.

Mont., and Fletcher[4] at Hanover, N. H. Results of the treatment of the reservoir of the Winchester, Ky., water supply were reported in 1905 by Moore and Kellerman[5]. Additional information was presented by Moore and others[6] during the same year in a symposium conducted by the New England Water Works Association. Prince[7], Caird[8], Kellerman[9], Huff and House[10], Hale[11] and others have added much to the knowledge on this subject following this early work. Ample experience has been gained to date to definitely establish the role of copper sulphate treatment in the control of algal tastes and odors in water works practice.

Chemical suppression of unsightly and ill-smelling algae scums, as a nuisance control measure in lakes and streams used for recreational purposes, has largely developed during the last two decades. A pioneering study in this field was conducted by Alvord[12] at Madison, Wis., who recommended in 1920 that copper sulphate be applied, under competent supervision, in sufficient amounts to maintain the lake waters in question in a clean and attractive condition. Experiments were continued for the next few years by the city and the University of Wisconsin, but it was not until 1925 that suitable procedures and equipment had been devised to carry out an effective treatment program.

Domagalla[13] has described the spraying facilities found most satisfactory, consisting essentially of a solution tank for copper sulphate and a power sprayer mounted on a scow. Use of this equipment supplanted the original practice of dragging burlap bags of the chemical behind a boat, with both more efficient and economical results. Domagalla also mentions his use of arsenical compounds for destruction of a variety of water weeds. In continuing work on the lakes at Madison and elsewhere up to the present he has further improved the technique of treatment and done much toward placing the control of aquatic nuisances on a sound basis.

Regulatory Measures

It has been inevitable that controversy would arise regarding the placing of chemicals like copper sulphate in waters frequented by fishermen. There have occurred certain instances where misguided enthusiasts, working on the theory "if a little does good, more should do better," have destroyed fish. These mistakes have resulted in demands that all practices of chemical treatment of this nature be prohibited or there be inaugurated adequate regulatory measures.

In Wisconsin, as a result of executive order, a committee was established in 1938 to review the whole problem of algae and weed control and recommend suitable policies and procedures of administration. It was finally determined that the work should be carried out on a continuing basis as one of the functions of the State Committee on Water Pollution, a statutory agency vested with broad powers for controlling pollution.

The 1941 legislature passed an act calling upon the Committee on Water Pollution: "To supervise chemical treatment of waters for the suppression of algae, aquatic weeds, swimmers' itch and other nuisance-producing plants and organisms." To this end the committee may conduct experiments for the purpose of ascertaining the best methods of such control. It may purchase equipment and may make a charge for the use of the same and for materials furnished, together with a per diem charge for any services performed in such work. The charge shall be sufficient to reimburse the committee for the use of the equipment, the actual cost of the materials furnished, and the actual cost of the services rendered plus 10 per cent for overhead and development work. The legislature also passed an amendment to the Town Sanitary District Act authorizing the control of aquatic nuisances by a Sanitary District and providing means for financing such measures.

The Wisconsin Committee on Chemical Treatment of Lakes and Streams consists of an attorney of the Wisconsin Public Service Commission; the chief biologist of the State Conservation Department; the chief chemist of the State Laboratory of Hygiene; and the State Sanitary Engineer of the State Board of Health. Its principal activities have been to obtain all facts available on chemical treatment, institute research to determine procedures to prevent unnecessary damage to fish and fish foods, and establish supervisory control over treatments so that chemicals would be scientifically applied rather than promiscuously used in the waters of the state. Laboratory and field investigations have been carried out with the aid of both special personnel and technical staffs of departments concerned.

The committee studied the effect of chemicals employed on various species and sizes of fish and some of their food material to determine toxic concentrations. Some of the results obtained are mentioned later. Spraying devices were tested and improved, dusting and broadcasting equipment for spreading chemicals was tried, and various other facilities to aid in obtaining reasonably good control over dosages have been studied. The biological laboratories at state fish hatcheries, and facilities at the University of Wisconsin were made available for this work. The committee has also developed a permit system in the supervision of treatment activities.

Apparatus and Treatment Procedure

During the summer of 1939 the Committee on Chemical Treatment of Lakes and Streams authorized treatment and special studies of several lakes in the state using copper sulphate in order to suppress objectionable algae growths. The first treatments were made with improvised apparatus which was largely of an experimental nature and was later changed somewhat to provide a more convenient means of treatment. A 50-gallon wooden barrel having a partition extending from the top to within six inches of the bottom was used as a solution box. Copper sulphate crystals of approximately pea size were placed in the barrel and hot water from the cooling system of the boat engine discharged into the barrel on one side of the partition. This liquid then passed downward under the partition and into the copper sulphate crystals and upon reaching the other side of the partition was practically saturated with copper sulphate.

A motor-driven portable pump was obtained and placed in the boat for the purpose of spraying the copper sulphate solution. Water was drawn from the lake and a small amount of the concentrated copper sulphate solution was introduced into the suction side of the pump. In passage through the pump the solution mixed with a comparatively large amount of lake water before being discharged through two 1-inch rubber hoses equipped with nozzles which were manually operated to spray the dilute copper sulphate solution onto the surface of the lake.

The first treatments were controlled by varying the speed of the boat and the amount of copper sulphate crystals placed in the solution barrel. It was found that this method would dissolve approximately 200 pounds of copper sulphate per hour. Later developments and refinements in the treatment process included the construction of a speedometer which gave an accurate measurement of the speed of the boat and also the installation of a small Venturi meter which measured the amount of copper sulphate solution being discharged into the suction side of the pump. Later another baffle was placed in the solution barrel and it was found that it was possible to obtain a saturated solution of copper sulphate which did not vary appreciably in strength.

Tables were also made, indicating the amount of copper sulphate necessary for the treatment of a given body of water and

it was found that the most satisfactory method of controlling variables was by changing the volume of saturated copper sulphate solution fed into the system. In this way the concentration of copper sulphate sprayed onto the surface of the water could be varied in proportion to the speed of the boat so that the resulting concentration in the lake water could be maintained at any desired figure. In hard-water lakes the usual amount of copper sulphate added was equivalent to 1 p.p.m. in the top four feet of water. At the present time the apparatus is being further developed by the construction of a portable photolometer with which the concentration of copper sulphate solution can be accurately checked.

It has been found that one of the most essential steps in treating a lake to suppress algae growths is a survey to determine the concentrations of algae, the areas of the lake which can be most beneficially treated, the hardness and other characteristics of the water, the depth of water, and type of algae present. With this information it is possible to accurately estimate the amount of copper sulphate needed and the areas which should be treated.

At the present time the Committee on Chemical Treatment of Lakes and Streams has apparatus available for the treatment of such lakes which can be used on a rental basis by any interested party under direct supervision of representatives of the Committee. The Committee furnishes supervision of such treatment in order that satisfactory control over the amounts of copper sulphate can be maintained. A charge is made to lake improvement associations and other groups sponsoring the work. The program has been quite successful in reducing nuisances from prolific algae growths and has not appeared to be harmful to fish life.

Toxicity of Copper Sulphate to Fish and Fish Food

Numerous tests have been made to determine the copper sulphate dosage required to kill fish. The relation between alkalinity and toxicity of this chemical to fish was shown by experiment under controlled conditions in aquaria, measured in time required to cause death. The relative toxicity of 25 p.p.m. copper sulphate to brown trout fry varied inversely with the alkalinity. With 6 p.p.m. of alkalinity in the water, all fish died in 2.5 hours; with 248 p.p.m. alkalinity there were four survivors after 12.5 hours.

The large discrepancy between the accepted toxic dose for bass (2.1 p.p.m.) and that found in recent studies (160 p.p.m. or more), was explained as follows: The toxic dose of copper sulphate for several species of fish (black bass, yellow perch, sunfish, and bullheads) was determined in distilled water. The values so obtained agree well with those appearing in the literature. Thus, the conclusion must be drawn that the tests of previous investigators had been made in either distilled water or in very soft waters.

Chemical examination of hard water treated with copper sulphate disclosed the fact that the calcium carbonates and bicarbonates react with the copper sulphate producing insoluble basic copper carbonate, which in hard water was shown to be non-injurious to fish. The rate of removal of the copper from solution as a relatively harmless precipitate is not, however, an instantaneous reaction. Several attempts were made without very reliable results to fix exactly the actual rate of removal. In general, however, it was found that the majority of the copper is removed from solution in about one-half hour.

The fish used in the above tests were less than one year old and averaged about 4 inches in length. In order to ascertain whether very young fish were extremely sensitive to the chemical, a test was made with bass fry one and one-half months old and averaging one inch in length. Again the mineral matter of the hard water offered a protective action and these fish were not affected until a concentration of 80 p.p.m. was reached. The results indicate that the young fish are more susceptible than older ones, but that there is still a large margin of safety present between dosages which destroy micro-organisms and those which will kill young fish.

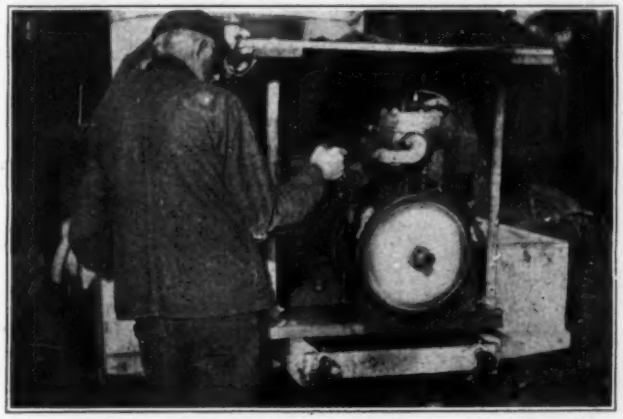
Results of the fish studies with various concentrations of copper sulphate have indicated: (1) The toxic doses of copper sulphate recorded in the literature for the various species of fish are correct only for distilled or very soft waters. (2) The mineral salts of hard waters remove copper from solution as an insoluble precipitate, thus increasing the amount of chemical which may be added before fish are killed. (3) The fatal dose for young large mouth black bass in hard water is 80 p.p.m.; for larger bass approximately 160 p.p.m. (4) Very short exposures of fish to high concentrations of copper sulphate produce high mortality.

Survival of Fish Food Animals in the Presence of Copper Sulphate:

A most important question concerns the effect of copper sulphate on animals other than fish; are certain kinds eliminated from a lake or so diminished as to reduce the fish food supply? A number of experiments undertaken on certain type organisms in various concentrations of copper sulphate showed the following: Rotifers survive low concentrations but were killed in concentrations ranging from 15 to 1,000 p.p.m. within a 30-hour period. Cyclops survived 4 to 15 p.p.m. concentrations for 88 hours, the length of the test. The common flat worm was found sensitive to a fairly low concentration of copper sulphate. All were dead within 24 hours in concentrations of 10 to 50 p.p.m. Amphipods proved to be very sensitive, even to low concentrations, and undoubtedly are reduced in numbers when lakes are given copper sulphate treatment. Species that proved to be very resistant to copper sulphate included the isopods, damsel fly nymphs, water beetle larvae, and caddis fly larvae. In general, experiments and field observations have indicated that most animal organisms are far more resistant to low concentrations than are the several species of nuisance algae. Therefore, the animal organism population will not be seriously reduced or permanently damaged by the methods now in use for controlling algae nuisances.

Relation Between Algal Density and Copper Sulphate Dosage

An experiment was set up to obtain some idea of the rate at which typical algal cells absorb copper from solution. Living plants of *Microcystis* were placed in water of 154 p.p.m. alkalinity in a 5-gallon aquarium. Copper sulphate was added to make a 2 p.p.m. solution. Samples for copper determination were then



A Trailer Unit
Motor powered spraying outfit for lake treatment mounted on a trailer.

taken at intervals. The conclusion was that "the amount of copper removed from solution by *Microcystis* is extremely small." Hence, for the control of this organism it appears it should not be necessary to increase the concentration of copper sulphate above 1 p.p.m. when treating lakes which have passed into an advanced bloom stage.

Swimmer's Itch

In the matter of "swimmer's itch," tests have shown the possibility of control of this difficulty by chemical treatment under certain circumstances, and accordingly the committee has been giving consideration to control of this nuisance as one important phase of its activities.

The most serious aspect of "swimmer's itch" probably is its detrimental effect on resort business. So far as has been determined, all cases of this type of skin irritation that have occurred in Wisconsin can be attributed to a single cause; namely, the accidental penetration into man's skin of the larvae of schistosome flukes (flatworms). These larvae, having developed in snails, emerge into the water where they will die unless they encounter the proper bird or mammal in which to complete their development. The infested birds and mammals in turn scatter eggs of the worm, which hatch and undergo development when they enter the snails.

This knowledge of the life cycle of the organisms causing "swimmer's itch" (more exactly termed schistosome dermatitis) is important because it suggests possible points of attack in

attempts to control the disease. Since the presence of this disease is of some economic importance to the state, studies have been carried out with the object of determining possible methods of controlling or combating the condition. The more important facts that have been learned to date will be presented here. A more extensive account of the researches substantiating the statements made have been published by Brackett (see References 14-19 inclusive).

Investigations in Wisconsin during the summer of 1938 and reliable accounts of the occurrence of this disease in earlier years indicate that, with the exception of a few localities, only a relatively small number of individuals are ordinarily affected. With such being the case, it is obvious that control measures that are at all extensive or expensive cannot usually be justified. In these places, where other control methods are impracticable, it may prove helpful to bathers if they rub themselves briskly and thoroughly with a towel immediately upon coming from possibly infected water and before the water has time to be removed from the skin by evaporation. Apparently most of the larvae penetrate while evaporation is taking place in the thin film of water covering the body. The rubbing crushes them while they are still on the surface of the skin before they have penetrated.

Particular attention is called to this prophylactic measure because it is simple, costs nothing, and puts the responsibility directly on the persons concerned. Likewise it is a procedure that can always be used anywhere, regardless of varying environmental conditions, a fact which is not true of other control measures to be discussed. At present the possibility of controlling the parasite during the mammal phase of its cycle is remote. Methods designed only to kill the larvae in the water would be temporary since the snails may shed great numbers of the larvae for a period of several weeks.

Chemical Solution Tanks and Power Spraying Unit in a Barge

Chemical dosages are controlled by regulating strength of chemical solutions and varying speed of barge travel indicated by a pendulum speedometer. Dosages are checked at intervals by colorimetric tests.

To eliminate the host snails, involved in outbreaks of "swimmer's itch," is undoubtedly the most effective and permanent method of preventing this annoying condition. It is evident from the absolute essentiality of snails in the life cycle of this parasite that the snail stage is a vital point of attack. The bulk of the studies have therefore been made on snails and their relationship to the disease. Amounts of copper carbonate as small as 3 lbs. per thousand square feet of bottom area have been used to kill the snails.

Rooted Weed Control

The elimination of rooted weeds involves the use of sodium arsenite which is a more dangerous chemical than copper sulplate. Arsenical compounds are considered as poisons. A dilute solution is sprayed onto the surface of the water over the plants. The plant is killed by the arsenic absorbed through the leaves and carried to the roots. The dosage depends on the weeds to be destroyed. The treatment is permanent until the area is reseeded. Experiments showed that fish (bluegills) can live at least six days in a solution that contains sufficient arsenic to kill plants. Further research showed that large mouth bass survived 232 hours in the presence of 6 p.p.m. Survival of 87 per cent was had in a 10 p.p.m. solution. Croppies and bluegills were unable to stand a 15 p.p.m. solution of arsenic.

During the summers of 1940 and 1941 the Committee on the Chemical Treatment of Lakes and Streams conducted a series of experiments in order to determine the practicability of using "Benochlor" products for the eradication of rooted aquatic weeds in the state of Wisconsin. Three Benochlor preparations used were Benochlor 3, Benochlor 3 T.D., and Benochlor 3 Special.

The following results are submitted as a progress report, inasmuch as the submission of a detailed final report is anticipated. Twenty-four test areas were set up in six bodies of water, some area being enclosed by a canvas fence supported by net floats and weights at the bottom to hold the fence in place. This permitted a definite control of the area treated.

In no cases were very promising results obtained with Benochlor 3.

In concentrations as low as 100 p.p.m. Benochlor 3 T.D. was effective in killing *Vallisneria, Potamogeton, Anacharis, Chara,* and *Myriophyllum* within 20 days. Further investigations will be made to determine the most desirable concentration to use.

In concentrations as low as 40 p.p.m., Benochlor 3 Special was effective in killing *Anacharis, Potamogeton, Zannichellis, Myriophyllum* and *Vallisneria* in 15 days. For Benochlor 3 Special or Benochlor 3 T.D. the weeds mentioned as being killed were the only ones present in the treated areas. Further investigations will need to be made to determine the toxicity of these compounds to aquatic fauna.

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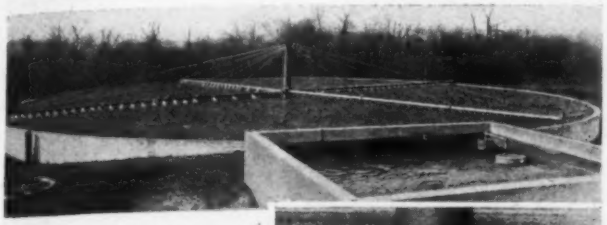

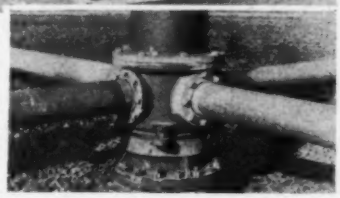

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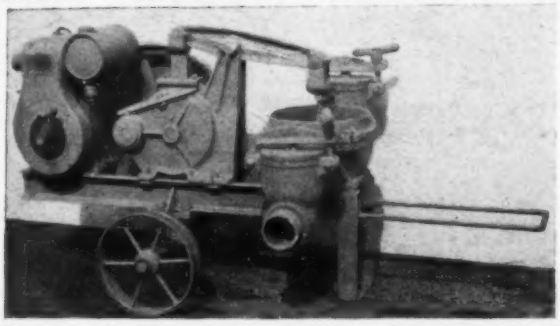

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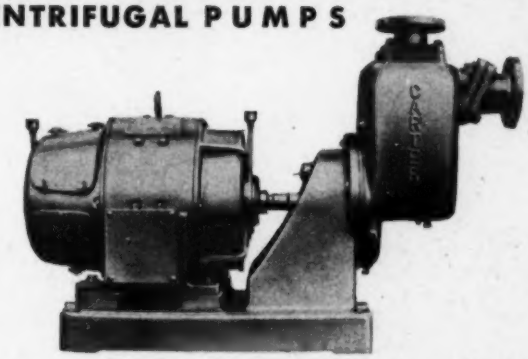

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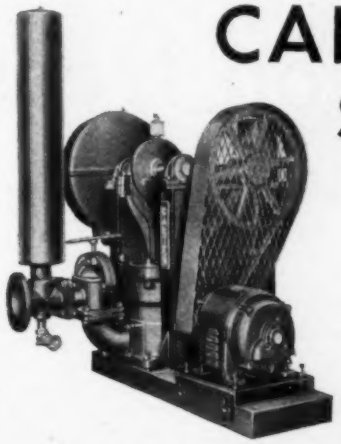

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THE MECHANISM OF CORROSION OF WATER PIPES

And Suggested Formulae for Corrosion Index

By THOMAS M. RIDDICK,
Consulting Engineer and Chemist, New York City

WE HAVE used lime and talked pH adjustment for corrosion control, but the question raised in the author's mind is this: Haven't we come to disregard many of the other significant factors in corrosion? The answer, based on what is to follow, is seemingly that we have.

Atmospheric rusting of steel has been squarely faced by the automotive industry, and their processes of Parkerizing, Bonderizing, etc., are now remarkably successful. It is high time that we of the water works field attempt to more closely correlate theory with practice, standard chemical analyses with specific pipe deterioration, and get away from well worn descriptive alibis such as "soft New England waters."

The suppression or retardation ("prevention" is surely a misnomer) of corrosion is more necessary today than ever before. All indications are that economic conditions will be more stringent for both municipalities and public utilities than heretofore, regardless of the outcome of the war. Both individually and collectively we must tighten our belts another notch and do as best we may with existing supplies and equipment. Household plumbing and the carrying capacity of distribution mains should be judiciously conserved.

A highly corrosive well or surface water that dezincifies yellow brass, removes the galvanizing from steel, and forms the familiar patina on copper tubing should not be delivered into the piping system without treatment simply because no inconvenience has been occasioned to date to the Water Department. If cut sections of household plumbing show relatively rank corrosion, undesirable things are also taking place within the distribution system, although it may not be evident in terms of red water or reduced carrying capacity if pipe lines have been in service less than twenty years. The water works official is the only person in a position to investigate and, if possible, reduce corrosion. Likewise, should it not be that the household plumbing investment of the property owner be given the same consideration as that of the Water Utility.

Two Prevalent Misconceptions

There are two prevalent misconceptions which seem inbred and self-perpetuating in Boards of Water Commissioners. The first is that current water rentals pay for the "Cost of Water." For certain municipalities this may be true, but more often the financial gross intake meets only current operating expenses with little allowance for proper maintenance and depreciation and no consideration is given to bonds retired out of the general tax or by assessment. The writer is familiar with two such water districts having relatively large distribution systems. The rate of $2 per 1,000 cu. ft. is about one-third the true charge if direct taxation is considered, but the true cost of $6 per 1,000 cu. ft. could not possibly be assessed directly without arousing the consumer's ire.

These facts should definitely be faced in figuring the increased cost which results from treatment for corrosion correction. For example, a certain corrosive well water with a CO_2 content of 12 ppm should be treated. The rate is $2 per M. and the required chemical dosage of lime, soda ash or sodium hydroxide is about 10, 29 and 11 ppm, respectively. If treatment was instituted, the additional cost per 1,000 cu. ft. would be 0.33, 2.7 or 2.4 cents, respectively. However, even the maximum increase (using soda ash) would be less than 1.5 per cent based on the prevailing $2 rate, or one-half of 1 per cent based on the "actual cost" of water to the consumer.

If the property owner was given his choice, i.e., "you may have a natural well water which is rather corrosive to your household plumbing at $2 per M., or a water which is as non-corrosive as is practicable to produce—providing maximum life to your household plumbing—and minimum red water for $2.03 per M.," there is hardly a question of doubt as to his selection.

Though these are the facts, either they have been poorly presented to Water Boards or else human inertia is a costly proposition.

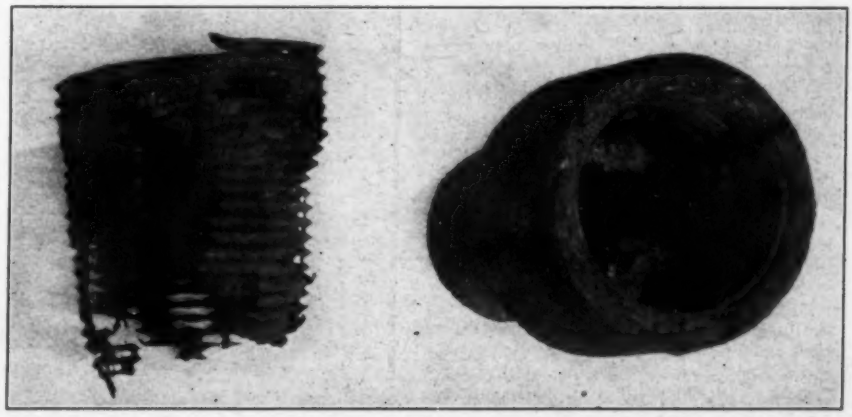
There is one other ghoul permanently stationed behind those Water Board Chairmen who offers the following argument whenever treatment is discussed—"We have *pure natural water*, and don't want any chemicals added." Thereafter the matter is closed. It seems impossible to get across the facts of the case, which are these: There never has been and never will be any "pure" natural water. All ground water contains "chemicals," principally limestone, gypsum, sodium chloride, sodium bicarbonate, and silica, and the gasses—carbon dioxide, oxygen and nitrogen. If a watershed (and all natural water comes from *some* watershed, regardless of its proximity to the well or intake) contains a large amount of gypsum and has marshy areas to contribute carbon dioxide, then a corrosive water is inevitable. If the watershed is composed mostly of limestone (with little gypsum) and few marshy areas, then the mineral content may be high and the water relatively non-corrosive. There are fewer waters in the latter class, and for some of these nature has been over-generous and difficulty may be encountered due to clogged hot water pipes.

The application of chemicals is simply an attempt to produce a "balanced water" applicable to domestic and industrial use, and suitable for conveying in metal pipe. The chemicals added are as "natural" as if nature had created them originally on the watershed.

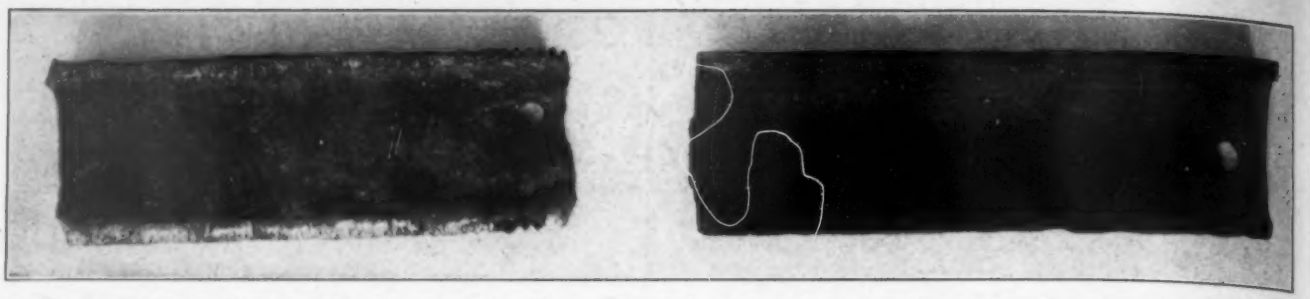
Two Stages of Pipe Life

The useful life of pipe should be divided into two distinct phases. The primary stage is that period during which pipe coatings remain intact or are gradually removed; and the secondary stage involves the direct attack of water on the pipe metal.

Section cut from 4" galvanized wrought iron distribution pipe—service 7 years; note uniform coating of red iron oxide streaked with zinc oxide.



(Left)—Section of 2" riser pipe at entrance to elevated wooden storage tank. Cause of corrosion—low pH, low alkalinity, high sulphate content and high carbon dioxide. (Right)—Corrosion due to use of dissimilar metals—brass vs. wrought iron. Pipe diameter reduced to ⅛ inch.



(Left)—Completely clogged section of cold water pipe—accumulation due to organic matter and iron in unfiltered surface supply plus iron derived from corrosion of distribution mains.

(Right)—Completely dezincified brass service line. Pipe is very brittle and failed through longitudinal split. Cinder fill was contributory cause.

If cast iron and steel pipe coatings are impervious and insoluble, and/or the water is relatively non-corrosive, the first stage may exist indefinitely. These are optimum conditions and result in the absence of "red water" and tuberculation, and pipe carrying capacity is sustained.

However, if coatings are pervious to water or soluble, and allow corrosive water to come in contact with the cast iron or steel, then the formation of creeping tubercles will tend to physically remove the remaining coating, thus exposing more pipe surface to the action of the water. Blisters (small masses of iron oxide overlying pits) form first and grow into tubercles unless the action of the water is inhibitive to the combination of oxygen with iron or steel.

Red water occurs in the second stage, but of far greater importance is the loss in carrying capacity of pipe lines. If water is pumped through transmission mains at relatively high velocity, the increase in power cost can be measured in terms of dollars. If the supply is wholly by gravity, the loss is manifest through reduced pressures on the distribution system and eventually creates a serious hazard from the standpoint of fire protection.

Normal corrosion of cast iron has never been feared from the standpoint of structural deterioration of such pipe to the extent of failure. If this was the case, superintendents and water boards would be mroe alert. Many municipalities, however, stand idly by and allow pipe to tuberculate to such an extent that 12-inch mains are reduced to the equivalent of 10 inches or less, without facing the facts.

This second stage of corrosion is one with which most water departments have to compete, though the use of cement or bituminous enamel linings today give more promise for the future. With pipe coatings removed and pipe surfaces roughened with blisters, all that can be done is to attempt to lessen the corrosivity of the water and its tendency to produce iron rust, which causes consumers' complaints, and to prevent small blisters from growing into large tubercles.

The second stage is more rapid than the first, and the accelerated rate is particularly emphasized after pipe cleaning has been necessitated. There is more than advertising copy in the paint manufacturer's slogan, "Save the surface and you save all." By this token, the time to protect the original surface is when a new distribution system is installed rather than 10 to 50 years later after the damage has been done.

Corrosion of galvanized steel and galvanized wrought iron are likewise characterized by two stages of deterioration, and the loss of carrying capacity, the stripping of threads and the occurrence of pin holes are evident remarkably soon after the zinc has been removed.

Copper tubing and yellow or red brass pipe have no protective coating other than the insoluble oxides and carbonates formed by reaction with water. In the case of these pipes there is only one stage of corrosion. It starts with installation and continues until replacement, or until a truly protective coating has been formed. Yellow brass, the most extensively (though unwisely) used of all copper bearing pipe, often requires renewal within five to fifteen years, and there are even instances of severe pitting of copper tubing (particularly class M and L) then necessitated replacement in an even shorter period.

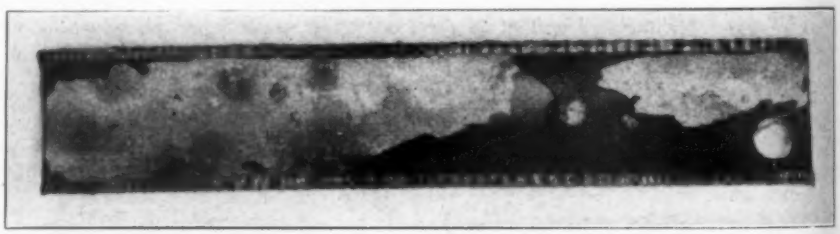
Types of Corrosion Encountered

Let us consider some of the types of corrosion normally encountered in water pipe. For want of a more descriptive term, the small nodules of red iron oxide which form on cast iron pipe will be called "blisters" and sizes above buck-shot will be classified as "tubercles." "Pits" will be considered as those areas (regardless of depth) underlying tubercles, or those exposed indentations created by removal of metal.

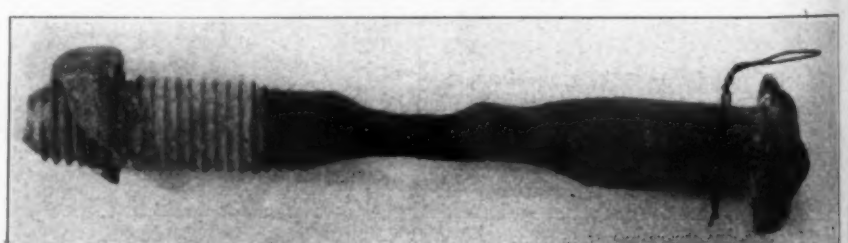
If a blister or tubercle is pried loose from a cast iron pipe-wall, we find that the tar or pitch coating is absent or cannot be identified readily. The volume of the tubercle is from three to ten times that of the original iron—or the volume of the "pit." The swelling action, due to formation of the oxide (hydrous oxide) has therefore been responsible not only for the formation of a protrusion which lessens pipe diameter and increases frictional resistance but it has pried away (in its formation) a sizable amount of pipe coating adjacent to the original point of attack, which was initially only microscopic in size.

Composition and Growth of Blisters

The composition of the blister is primarily red iron oxide (Fe_2O_3). On the underside, however, and on the surface of the shallow "pit" we may find a predominance of black crystalline magnetic iron oxide (Fe_3O_4). This can be identified microscopically or by lightly scraping the underside of a freshly removed tubercle and subjecting the crystals to the action of a bar magnet. It must be that the magnetic oxide of iron is the first product formed, since it lies next to the metal surface, and that the Fe_2O_3 is the final stage of oxidation. It is possible that the very



Copper tubing after 5 years' service. Failed through pitting. Note heavy formation of copper carbonate. Cause, possibly electrolysis.



Acid type corrosion of ¾" coupling bolt for Universal Pipe. Note absence of any iron oxide. Failure probably due to small amount of cinders in fill.

first stage was the lower oxide, FeO. The three stages of oxidation in their simplest expressions would be:

$2\,Fe + O_2 = 2\,FeO$ (ferrous oxide)
$6\,FeO + O_2 = 2\,Fe_3O_4$ (magnetic iron oxide)
$4\,Fe_3O_4 + O_2 = 6\,Fe_2O_3$ (ferric oxide)

If blisters were "watertight," they would cease to grow from within. Enlargement of small blisters into large tubercles is probably accomplished in three ways:

1. Growth from *without*, by deposit of iron oxide derived from the water per se, or from corrosion of the distribution system by the water en route.
2. Growth of the tubercle from *within* by the passage of water (carrying oxygen) through the amorphous red iron oxide to the pipe metal.
3. Growth of the tubercle from *within* by the passage of water (carrying oxygen) through the peripheral seal of the tubercle, to the pipe metal.

In the first stage of growth, it is probable that oxygen gains admission through the relatively thin coating of amorphous red oxide. As growth advances, more oxygen is admitted around the ever enlarging periphery of the nodule, and less through the body of the growth. The nodule is generally held to the pipe metal by the crystalline interlocking of the magnetic iron. When tubercles are removed by "prying loose," they generally remain intact, which indicates that the plane of structural weakness lies in the under zone of magnetic iron next to the metal. It is logical to presume that a thin crystalline plane offers less resistance to the passage of water than the dense mass of red iron oxide forming the body of the nodule.

What is the property of red iron oxide which holds it together in a ceramic like mass? The hydrous or anhydrous forms of the pure compound will not agglomerate and harden at normal temperatures. When tubercles are ground in a mortar and analyzed, the silica content (or what we differentiate as silica) is several per cent. Silicates are the most widely used cementing agents in both nature and industry, and it is logical to assume that this is one of the factors which is responsible (perhaps fortunately so) for tubercle formation. If water has a pronounced tendency to corrode metal, it is preferable to have it form a protective scale rather than to continuously discharge ferrous bicarbonate or iron oxide to the consumer. If silica is present in the tubercle, its source must be the water itself if no silicates have intentionally been applied to suppress corrosion.

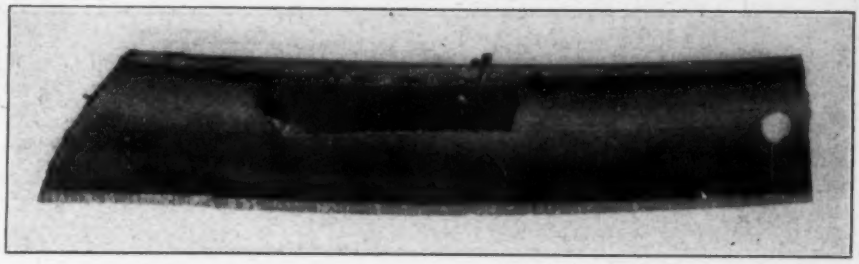
Again, It Pays to Save the Surface

If water treatment is necessary, it should begin when the distribution system is installed. Although little published research exists on the subject, it is likely that high carbon dioxide and low pH has a tendency to dissolve and penetrate pipe coatings more rapidly than neutral or alkaline waters.

Once pipe coatings are removed, water treatment may "reduce" but never "eliminate" corrosion. The manner of inhibiting the further oxidation of iron or steel seems to be:

1. To precipitate or force calcium carbonate out of solution to form a "protective film" or "protective coating" on the walls of the pipe.
2. To lessen the tendency of iron to dissolve and/or unite with the oxygen content of the water.
3. To make existing blisters, tubercles, or coatings of iron oxide more impervious and impenetrable, thereby more effectively preventing the contact of the oxygen carrying water with the pipe metal.

The writer believes that the first principle has been over-em-



Excellent example of nature's "overtreatment" of a well water. Protective scale of calcium and magnesium carbonate and sulphate formed in a hot water line. Jet black color, due to manganese. Removed from service due to clogging.

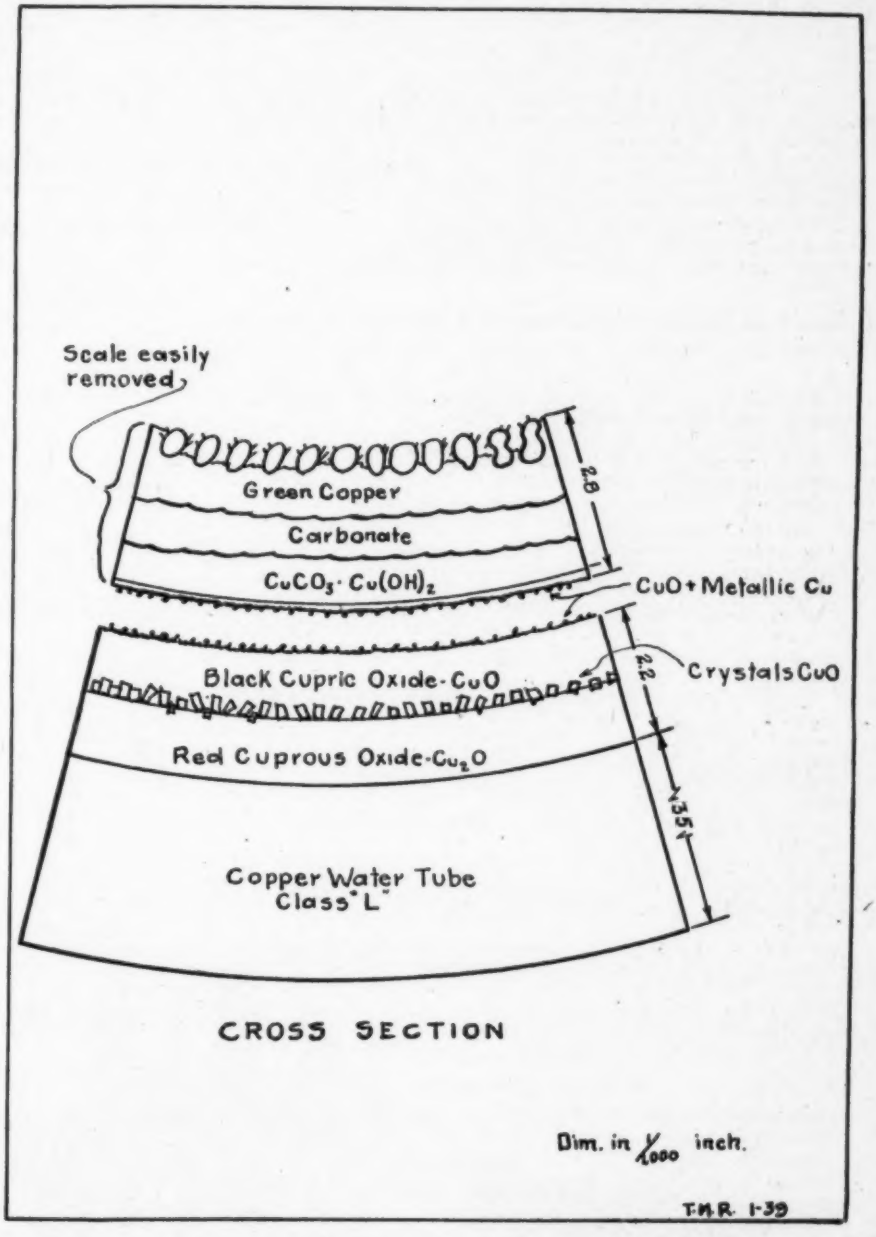
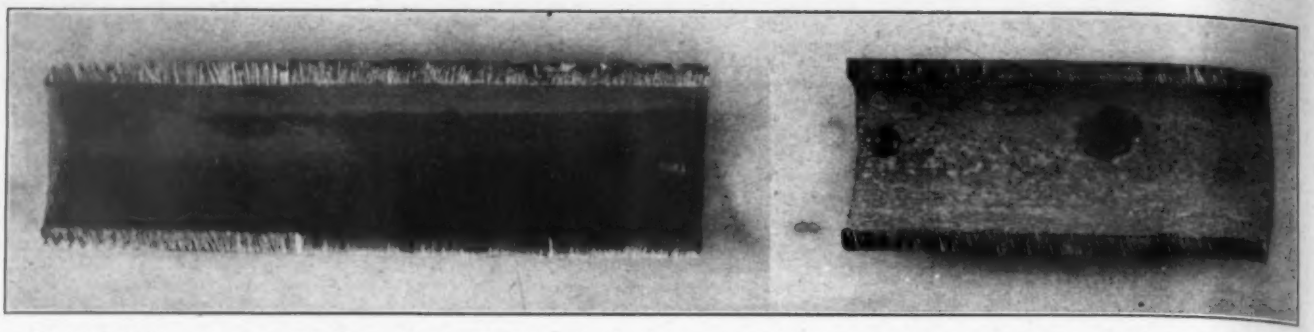


Plate 1—Sketch of a Section Cut From Copper Tubing Which Suffered Severe Corrosion

(Under the microscope this section, as sketched, revealed the mechanism and end products of the progressive corrosion as explained in the text.)



(Left)—Split section of yellow brass house plumbing completely protected by coating of iron oxide from the distribution main. (Right)—Dezincification of galvanized wrought iron.

phasized. There are certain natural non-corrosive waters which contain insufficient mineral salts, and have pH values entirely too low, to ever force calcium carbonate out of solution. Their non-corrosive properties must surely be derived from the two principles last mentioned. If alkalinity, pH and calcium content is maintained at a point to provide *adequate* "film protection" to cold water lines in winter months, then the change in temperature from between 32 and 40° F. to between 140 and 160° F. should clog a lot more hot water systems than we hear about, and consumers are never remiss in voicing such complaints to the water utility.

The More Important Functions of Treatment

The writer feels that the more important functions of treatment are to reduce the tendency of the water-borne oxygen to unite with iron, and to further cement or "waterproof" the iron oxide already present in the pipe, whether it be in the form of a surface film, blisters or tubercles.

This cementing action is quite apparent when we observe water containing less than a "trace" of iron, if any, drawn from mains coated with tubercles to a thickness greater than one inch.

Galvanized pipe, either steel or wrought iron, first exposes a zinc surface to the attacking water. Primary corrosion results in the formation of both zinc oxide and carbonate. It is likely that the oxide is first formed, which might of itself form a protective coating. Carbon dioxide, however, seems to combine readily with the oxide to form a coarse crystalline carbonate, which is removed by gradual solution as well as breaking away from the pipe walls in small pieces.

Once the protective zinc has been attacked sufficiently to allow water to reach the wrought iron or steel, the upheaval of scale is more rapid due to the bulking effect of iron oxide. Thereafter, the pipe walls become coated with blisters or scale of red iron oxide, and subsequent deterioration seems comparable to cast iron tuberculation. Steel is, as a rule, attacked more rapidly than wrought iron, and its life may be quite short after complete removal of zinc.

Zinc is more resistant to corrosion than iron or steel, else its application to pipe surfaces would be pointless. Again the emphasis should be on preservation of the original surface.

Red brass, yellow brass, and copper tubing have no protective coating other than the surface film of the metal itself. Yellow brass pipe is unreliable for most waters and should be barred from plumbing use. Gradual deterioration is through the removal of the zinc to form oxide and carbonate scales although a sizable amount of copper is also present. Failure occurs

1. At the pipe threads, particularly if these are cut deep.
2. By gradual reduction of wall thickness, and pitting to produce "pin holes."
3. By complete dezincification, which leaves the copper in a semi-crystalline state.

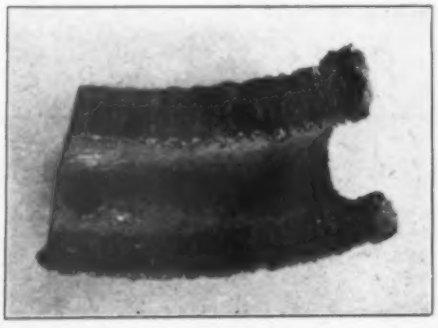
Tell-Tale Indications of Yellow Brass Deterioration

The occurrence of a "white powder" at joints of yellow brass is common, but a visual inspection of piping in service for several years will give little indication whether the powder is zinc carbonate or white lead oxide—a compound often used in "pipe dope." Microchemical analysis gives ready identification, however, and if zinc is predominant, the remaining years of useful service of the yellow brass are numbered.

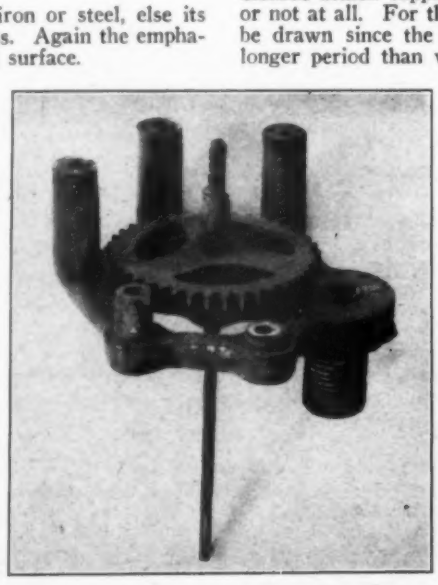
Several years ago the writer instituted treatment for an estate where yellow brass was used throughout, and many sections had "pin hole leaks," necessitating pipe replacement. Copper carbonate was present in sufficient amounts to impart a heavy green stain to laundered goods and to porcelain beneath dripping faucets. The complete neutralization of CO_2 and raising the alkalinity about 40 ppm completely inhibited the further discharge of copper carbonate, and since no leaks have subsequently occurred, it is reasonable to state that corrosion or further dezincification has been very greatly reduced.

Complete dezincification with embrittlement of pipe metal is not common. It is possible, however, and small fragments could easily be broken from one specimen examined by the writer. The plane of fracture showed no metallic copper whatsoever, and this could only be observed by cutting through the specimen with a saw.

Red brass, containing 15 per cent zinc, seems more resistant to corrosion even than copper tubing, or expressed conversely, some waters very low in mineral solids and high in carbon dioxide attack copper tubing readily, but red brass either slowly or not at all. For the less corrosive waters, little comparison can be drawn since the life of both is, and should be, for a much longer period than we have on record today.



Impervious green coating on lead service pipe.



Corrosion of meter parts. Brass frame, shaft and gear coated with iron oxide.

Meter disc chamber badly pitted and encrusted with copper carbonate.

Some Observations of Corrosion of Copper Tubing

A section of badly corroded type L copper tubing, which had pitted-through or "pinholed" in spots, is sketched to scale in Plate 1. The surface scale, which was easily removed in long cylindrical rolls, was green copper carbonate. This was bound to the scale adhering to the pipe wall by black cupric oxide, which was distinctly crystalline in structure. The method of attachment was therefore quite parallel to that of tubercles on cast iron pipe walls. Beneath the cupric oxide was a layer of red cuprous oxide Cu_2O, which apparently was being formed from the metal of the tubing. This progressive oxidation somewhat substantiates the conclusion that the first oxide formed in tuberculation of cast iron pipe was ferrous oxide FeO, which is not so readily identified as the red cuprous oxide, Cu_2O.

The order of oxide formation, expressed in simplest terms, is as follows:

$4\,Cu + O_2 = 2\,Cu_2O$ (cuprous oxide)
$2\,Cu_2O + O_2 = 4\,CuO$ (cupric oxide)
$2\,CuO + H_2CO_3 = CuCO_3 \cdot Cu(OH)_2$ (cupric carbonate)

If a standard mineral analysis had been made of the *removable* scale only, the stages of oxidation or carbonation would not have been manifest. This suggests the necessity of employing microchemical methods, as was done in this instance, and the need of a more fundamental study of the progressive stages of corrosion.

In the absence of carbon dioxide, it is probable that only cuprous and/or cupric oxide would be formed, which serve far better as a protective film than the more porous cupric carbonate.

This conclusion points strongly to the presence of carbon dioxide as a potent factor in corrosion, but it does *not* explain why *some* supplies containing high amounts of CO_2 do not actively attack copper tubing.

Practical Observations vs Theory

The writer has long felt that the approach to corrosion in the water works field has followed too much the same line of reasoning. And, axioms (some formulated years ago for specific supplies) have too generally been accepted and applied. There are no two waters the same, and it is only by viewing corrosion of many supplies that we may form a concept of the fundamental underlying principles.

It is often true that practice precedes theory, and with this in mind, the writer has tried to disregard some of our accepted tenets and evolve a rational approach from the standpoint of *evidence* rather than theoretical reasongin and what are accepted as chemical laws.

If we have a practical knowledge of many supplies, natural or treated, they may be classified as "non-corrosive," "corrosive" and "very corrosive," based only on (1) frequency of hydrant flushing on dead ends and time required for hydrants to flush "clean," (2) occurrence of red water on the distribution system, (3) life of galvanized steel, galvanized wrought iron, copper, red and yellow brass pipe, and hot water boilers, (4) tuberculation of mains, (5) loss of pipe carrying capacity, (6) stains on porcelain, (7) occurrence of brown or green stains on laundered materials, (8) dezincification of galvanized steel or wrought iron, yellow brass pipe, etc., etc.

If the chemical analyses for such classified waters are compared, we find little if any correlation for any *one* constituent and *this particularly applies to pH*. But considering the mineral and gaseous components, a general pattern seems to be evolved.

If we occasionally find natural, untreated, well and surface supplies which are relatively non-corrosive, should we not consider them somewhat as a criterion when we begin to alter the characteristics of water by the addition of lime, soda ash, caustic soda, silicate, and the aluminum and iron coagulants?

I do not infer that nature cannot be improved upon. It can, as is evidenced by the applications of vitamins to aid plant growth, but until we have at least *equaled* natural processes, let us not try to improve upon them.

The physical and chemical tests which should be employed in the evaluation of any water are: Turbidity, Color, Odor, Carbon Dioxide, Alkalinity, pH, Hardness, Iron, Manganese, the Nitrogen Determinations, Chlorides, Temperature, Dissolved Oxygen, Silica, and Solids.

The complete mineral analysis is far too time consuming to ever be used from a practical standpoint, unless a lot more time and money is expended than heretofore.

To judge the corrosive qualities of a water *per se* (not the *effects* of corrosion) the writer believes that the following tell most of the story: Carbon Dioxide, Alkalinity, Hardness, Silica, Dissolved Oxygen, Chlorides and Nitrates.

The two constituents last classified are generally present in such low amounts (in Atlantic coastal supplies at least) as to render their inclusion rather dubious. Oxygen can only be determined accurately in the field and is not a "routine" test. Silica should definitely be included in routine examinations, although the method of analysis is of doubtful accuracy.

Three Empirical Formulae Evolved

The writer has evolved three purely empirical formulate to numerically express the corrosive tendencies of water, based on correlation of Standard Methods tests with the physical manifestations of corrosion previously listed.

They definitely take hydrogen ion concentration (pH) into consideration by the inclusion of Carbon Dioxide and Alkalinity, and I believe evaluate their true importance more accurately than does the pH test.

Formula 1 is most applicable to routine analyses as performed by most commercial and state laboratories, and is as follows (analytical values are expressed in ppm.):

$$(1)\ \text{Corrosion Index} = [CO_2 + \tfrac{1}{2}\,(\text{Har.} - \text{Alk.}) + Cl_2 + 2N]\,\frac{75}{\text{Alk.}}$$

It gives numerical values ranging from about 5 to 150, which are evaluated by the writer as follows:

0-5	Extremely non-corrosive
6-25	Non-corrosive
26-50	Moderately corrosive
51-75	Corrosive
76-100	Very corrosive
101+.	Extremely corrosive.

This formula is generally applicable to waters on the eastern seaboard. It may apply or may be totally inapplicable to those of the west or midwest. It holds primarily for natural waters but seems to give good interpretations for treated supplies.

There are two other factors of prime importance which have been omitted since many laboratories do not make these tests as routine—they are Silica and Dissolved Oxygen.

When the silica test is made, the following correction may be applied:

$$(2)\ \text{Corrosion Index} = \text{CI}\ (1) \times \frac{10}{SiO_2}$$

If dissolved oxygen is also included, the formula is:

$$(3)\ \text{Corrosion Index} = \text{CI}\ (1) \times \frac{10}{SiO_2} \times \frac{DO + 2}{\text{Sat. DO}}$$

$$\text{or} = \text{CI}\ (2) \times \frac{DO + 2}{\text{Sat. DO}}$$

It is observed that the formulas particularly stress total alkalinity and non-carbonate hardness. The writer is firmly convinced that the latter, which is often magnesium sulphate, is a potent factor in corrosion.

Several natural "non-corrosive" waters are listed in Table 1. pH values are below those normally carried in alkali treated waters and range from 6.3 to 7.8 Corrosion indices are uniformly low, however, except for the well water having a value of 62. The inhibiting factor in this case is naturally the low dissolved oxygen. Obviously formula 3 would have been more applicable. The only common characteristic of the group is *low non-carbonate hardness*. Although these natural waters are listed as non-corrosive, there is no doubt but that complete neutralization of carbon dioxide and the maintenance of several parts per million of carbonate alkalinity would have rendered them still less aggressive.

Several extremely corrosive waters are shown in Table 2.

Again the only common characteristic is high sulphate content, though the effect of low alkalinity seems pronounced. In the reservoir water and the shallow well supply last listed, the writer is convinced that sufficient alkalinity could not be supplied by lime without excessive pH, and in these instances soda ash or caustic soda would be the preferable chemical to apply.

It has been known for some time that waters low in carbon dioxide and alkalinity could not be given sufficient lime to form a protective coating, but the writer feels that there is some further principle involved which may be roughly expressed as a hardness-alkalinity or carbonate-sulphate ratio.

An example of the application of lime or soda ash to alum treated water, either before or after secondary aeration, is shown in Table 3.

Here is indicated the advisability of adding lime or soda ash *before* rather than after secondary aeration. The Index is probably somewhat exaggerated, though plant operation showed that corrosion was reduced by substituting soda ash for lime in post

aeration treatment, and a split dosage of pre lime and post soda ash has been instituted.

Based on correlation of chemical analyses with pipe deterioration, the following factors tend to reduce corrosion:

(1) Low non-carbonate hardness, or low sulfate content.
(2) High alkalinity.
(3) High silica content.
(4) Low carbon dioxide.
(5) Low oxygen concentration.
(6) Low temperature.

Those tending to accelerate corrosion are the converse of the above.

The writer wishes to emphasize that the empirical corrosion indices listed were prepared on a cut and try basis over a period of years and are naturally subject to discrepancies and to change. They constitute a "rule of thumb" method for evaluating the corrosive qualities of a water, based on normal chemical analyses, and admittedly there is no phase of water treatment that can be competently handled on such a basis.

The formulae are presented with the hope they may elicit further practical research, and that a sufficient number of operators, chemists and superintendents will apply them, to either substantiate, improve, or entirely discredit the Indices.

The writer will be glad to receive reports from water works personnel as to their applicability to specific supplies.

TABLE 1—RELATIVELY NON-CORROSIVE WATERS

Results in parts per million

Source	River	Spring	Deep Well	Deep Well	Deep Well	Spring
Carbon Dioxide	1	1.5	18	16	8	0
Alk. (Bicarb.)	100	66	30	92	130	28
Hardness	104	76	34	88	131	28
Chlorides	4	4	5	5	9	3
Nitrates	1	0.4	0	0	1	0
pH	7.9	7.3	6.3	6.8	7.4	7.8
Silica	..	..	7	..	..	..
Dissolved Oxygen	..	..	2.4	..	..	..
Corrosion Index*	7	13	62	17	11	8

*Computed with formula (1).

TABLE 2—VERY CORROSIVE WATERS

Results in parts per million

Source	Shallow Well	Shallow Well	Reservoir	Deep Well	Deep Well	Shallow Well
Carbon Dioxide	11	18	3	14	18	26
Alk. (Bicarb.)	5	9	9	18	34	8
Hardness	60	22	20	34	60	46
Chlorides	20	5	2	3	5	13
Nitrates	11	1	0	0.5	1	1
pH	5.5	5.8	6.6	6.1	6.6	5.5
Silica	..	2	5	6	..	..
Corrosion Ind.*	1050	267	92	108	82	560

*Computed with formula (1).

TABLE 3—EXAMPLE OF EXTREME VARIATION IN CORROSION INDICES DUE TO POINT OF APPLICATION OF ALKALI

Results in ppm.

	Raw W. After Aeration	Filtered Water	Filt. W. After Sec. Aer.	Finished Water— Lime Before Sec. Aer.	Lime After Sec. Aer.	Soda Ash Before Sec. Aer.	Soda Ash After Sec. Aer.
Chem. Dosage, ppm	..	..	..	13	4	36	10
CO_2	2	15	4	0	0	0	0
Alk. (Bicarb.)	38	38	38	56	43	38	38
Hardness	18	3	3	21	8	37	12
Chlorides	3	3	3	3	3	3	3
Nitrates	1	1	1	1	1	1	1
D.O.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.
pH	6.9	5.6	6.0	7.9	7.9	7.9	7.9
Corrosion Ind.*	71	940	660	80	210	11	110

*Computed with formula (1).

COPPER AND HEALTH*

The effect of copper on health is a subject of such importance to all users of copper and brass and copper sulphate for algae control, that the conclusions in an article read before The New England Water Works Association are given below:

1. The copper content of domestic drinking water after passing through copper or brass pipe or tubing, even if a slight amount of copper is taken into solution, is not harmful to health. It may indeed be beneficial.

2. All water supplies intended for domestic use after passing through a proper installation of copper or brass pipe or tubing will contain but a small percentage of the permissible copper content, if any at all.

3. The permissible copper content of domestic water based on a consumption of one gallon of water a day should apparently not be greater than 20 p.p.m.

4. It is unlikely that health will be injured by copper because, where the copper content is above 5 p.p.m., the taste of the water will generally be so disagreeable that it will be virtually impossible to drink it.

5. No anxiety need be felt about a proper installation of copper or brass pipe or tubing, because it has been shown that with acid water having a pH value of about 6.5, the copper content is generally only about 0.5 p.p.m., even after standing in the pipe lines for an appreciable length of time.

6. The treatment of reservoirs with copper sulphate to rid them of undesirable microscopic growths has no injurious effect on health.

*Journal N. E. W. W. A., 44: 4, December, 1930.

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The outstanding benefits which may be obtained from the use of silicate of soda in the preparation of a coagulant aid are:

1. More rapid formation and settling of floc.
2. Increased capacity in upflow or basin type plants.
3. Lower turbidity applied to filters.
4. Longer filter runs; less backwash.
5. Reduced chemical cost.
6. Better quality of finished water.

When to Use

Silicates have been successfully used:

1. To obtain good floculation when formation of floc is otherwise difficult due to (a) low temperature, (b) low turbidity, (c) unfavorable pH, (d) inadequate mixing and settling.
2. To reduce excessive coagulant consumption.
3. To produce excellent floc in softening low magnesium well waters, eliminating the use of alum.
4. To improve magnesium removal in waters of high magnesium hardness.
5. To reduce objectionable iron content.
6. To improve treatment of water that is not to be filtered.
7. To reduce cost of new plant construction.

Proper Grade of Silicate

Use only a silicate of known quality. The PQ Silicate recommended for coagulation is:

"N" Brand, Ratio $Na_2O:SiO_2$ 1:3:22; 8.9% Na_2O, 28.7% SiO_2, 41° Baume, weight 11.6 lbs. per gallon.

How to Use

Diluted "N" Brand Silicate is reacted with an acid alum, iron salts or ammonium sulfate. The choice of the reacting chemical depends on the character of the water and the sterilization procedure. For example:

When chloramine is employed, use the N-Sol-A Process (Pat. Applied for). This is prepared by combining "N" Brand Silicate and ammonium sulfate. It eliminates the use of acid, permits preparation of higher concentrations and provides factors of safety in the use of silica sol in lime softening.

Where chloramine is not employed, the N-Sol-B Process (U. S. Pat. 2310009) may be used. This is "N" Brand combined with alum.

Also, there are various modifications of the procedures involving acid neutralization (Baylis Sol).

Several methods of preparing the sols are practiced. Some involve aging. Both batch and continuous preparation are feasible using solution feed equipment. Special recommendations are made for use with lime softening.

PQ Assistance

The patents and process improvements developed by the research chemists of the Philadelphia Quartz Company are available without royalty. Technical data, samples of "N" Brand and suggestions for jar tests forwarded on request.

Other Silicate of Soda Uses

PQ grades ranging from $3Na_2O.2SiO_2$ to $Na_2O.3.9 SiO_2$ are adapted for numerous industrial uses. A few of interest to water works are:

Corrosion Prevention: Silicates of Soda are effective in protecting water mains and pipes.

Zeolite Protection: When required for the protection of synthetic zeolite, "N" Brand is applied to the water to be softened.

Acid-proofing Concrete: The PQ Silicate treatment protects concrete against deterioration from hydrogen sulfide, alum, ammonium sulfate and acid solutions.

Alignment chart available to users of silicate for water coagulation.

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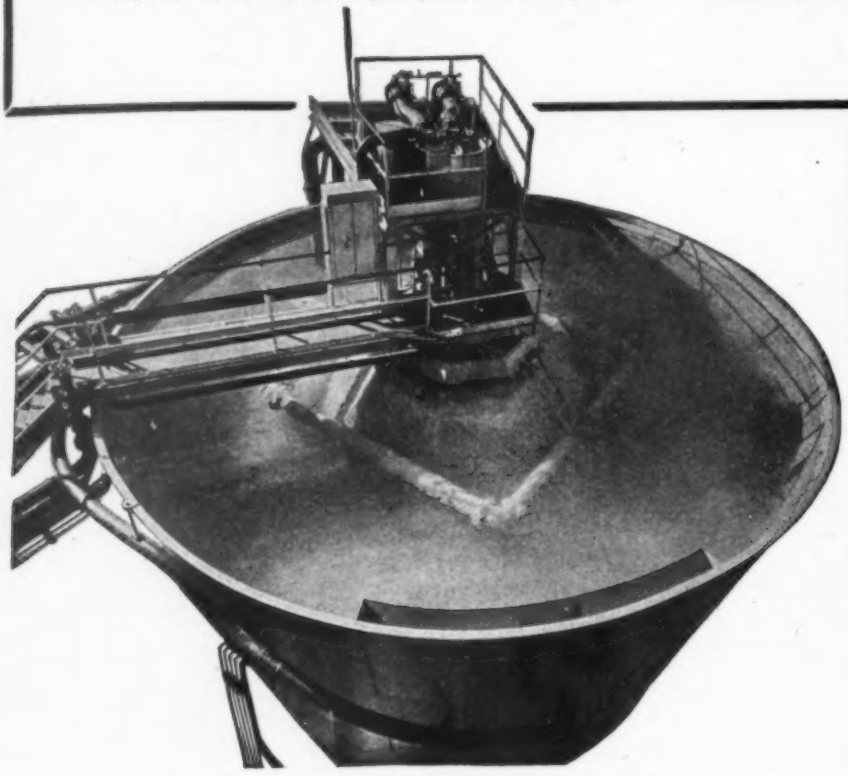

FASTER, MORE ECONOMICAL COLD LIME TREATMENT

. . . WITH PERMUTIT'S NEW SPAULDING PRECIPITATOR

This revolutionary new equipment removes hardness and suspended solids in a much shorter detention period, saves chemicals, takes only half the space of old-type plants. The raw water and chemicals are mixed in a compartment where they are agitated with the suspended sludge from previously treated water. This speeds precipitation. The water and precipitates then pass into the filter upflow compartment which has a gradually increasing cross-section. The gradually reduced velocity of upflow supports the sludge filter at uniform density throughout the filtering zone. A rate of flow is reached at which the sludge is no longer supported, but drops sharply out. The effluent is clear, and may not need further filtration.

Permutit makes every type and size of water conditioning equipment. Here are a few:

ZEOLITE WATER SOFTENERS

In Permutit's pressure zeolite softeners, a single multi-port valve, operated automatically or manually, conducts the raw water into a shell, distributes it evenly through a bed of zeolite and collects it, the water flowing to service completely softened. The valve also controls backwashing to clean the bed, regeneration with brine, and rinsing. Gravity zeolite units are also available.

PERMUTIT'S SPIRACTOR

The new cold lime soda water softener based on "catalytic precipitation" principle. Soft water in 5 minutes . . . no settling or sludge . . . Saves space and time.

PERMUTIT'S DEMINERALIZER

Produces the practical equivalent of distilled water—at a cost as low as 5% of distillation cost.

WATER FILTERS

Automatic and manual, gravity and pressure.

IRON REMOVAL FILTERS

FLOC FORMERS

SWIMMING POOL EQUIPMENT

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WATER CONDITIONING HEADQUARTERS

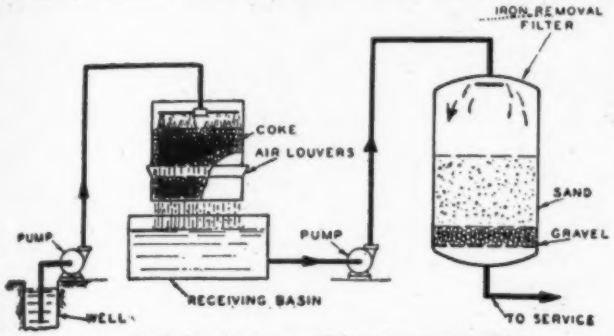
REMOVAL OF IRON AND HARDNESS

By DANIEL J. SAUNDERS

The Permutit Company, New York, N. Y.

The following describes some of the difficulties experienced in industry and in the home due to the presence of iron and hardness in water and, at the same time, outlines methods that can be employed to overcome such difficulties, under varying sets of conditions.

When iron is present in a water supply in an amount greater than 0.3 p.p.m., it causes unsilghtly yellowish or black stains on bathroom fixtures, gives a metallic taste to drinking water, reacts with other reagents used in dye houses, laundries, paper mills and tanners where, for example, it combines with tannin in leather and forms black iron tannate; deposits in Municipal distribution systems, thus not only increasing the friction through



A Simple Coke Aerator and Iron Removal Filter.

the mains which increases pumping costs. but at sudden high rates of flow these deposits loosen iron rust itself which is delivered to the users. Further, the growth of iron bacteria, such as Crenothrix, is also promoted by its presence.

The type of treatment plant required to remove iron is determined by a number of factors such as: character of the water (especially the factors interfering with oxidation reactions) engineering conditions and the purpose for which the water is to be used.

Iron and Manganese Removal

In general, iron (also manganese), can be removed from well waters by two methods:

1—Oxidation to the insoluble higher oxides and hydrates followed by filtration.

2—Removal by base exchange, by employing correctly selected base exchange zeolites.

However, all waters and particularly surface supplies, do not respond readily to oxidation reactions. As just mentioned, there are interfering factors to be given consideration such as:

Free Carbon Dioxide

High amounts of free CO_2 or any acid will interfere with the oxidation reactions going to completion. Therefore, in such cases thorough aeration. or addition of alkalis, or both, are necessary The addition of only 0.14 p.p.m. of oxygen per 1 p.p.m. of iron is theoretically required in the normal oxidation reaction. This quantity is insufficient when free CO_2 or any acid is present.

Low Total Solids

With waters of this type usually, even though a thorough removal of the carbon dioxide is effected by efficient aeration, it is necessary to supplement that step in the treatment by additional steps, as will be described later.

Organic Matter

Iron or manganese present in organic combinations is not removed by simple aeration and filtration. Coagulants fed into floc forming aggitating devices to accelerate floc formation and sedimentation tanks or basins must precede the filters.

Excessive Aeration

This has been known to interfere with the complete removal of iron and especially manganese. In such cases, restricting the aeration, i.e., limiting the absorption of the oxygen to a fraction of saturation, gives better results.

Types of Plants

Waters Low in CO_2 and Relatively Low in Iron Responding Readily to Oxidation

A small amount of air can be introduced by sniffling air into the suction side of the well pump for oxidation purposes. The well pump can then pump the oxidized water directly through either a single pressure filter or, to avoid frequent backwashings, through a coarse pressure filter followed by fine pressure filter direct to storage or use, thus making repumping unnecessary.

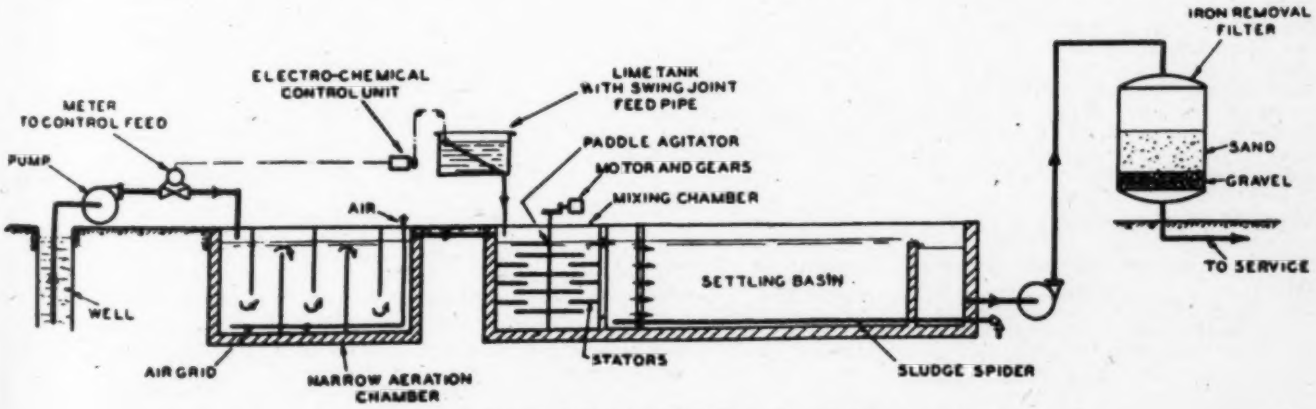
However, where preferred, gravity filters can be employed. Air wash systems should be employed where their use is deemed advisable.

Waters High in CO_2 Requiring CO_2 Removal by Alkali Feed or Efficient Aeration Before Final Filtration

In this case, the arrangement just described can be employed p ovided an alkali feed is installed to neutralize the CO_2. However, as air is free, if the quantity of water being pumped is appreciable, an efficient type of aerator should be installed, preferably either a coke tray type or degasifier bubbling type to insure exposing the water to the air in thin films or drops so that each particle of water contacts air low in CO_2 content. However, should the iron present in the raw water be very high, a sedimentation tank or basin may be required.

Waters of Low pH Value That Do Not Respond Readily to Oxidation

In such cases, following aeration, lime or soda ash is fed by means of a proportionating chemical feed to a sedimentation tank or basin (equipped with floc formers for aggitating purposes).

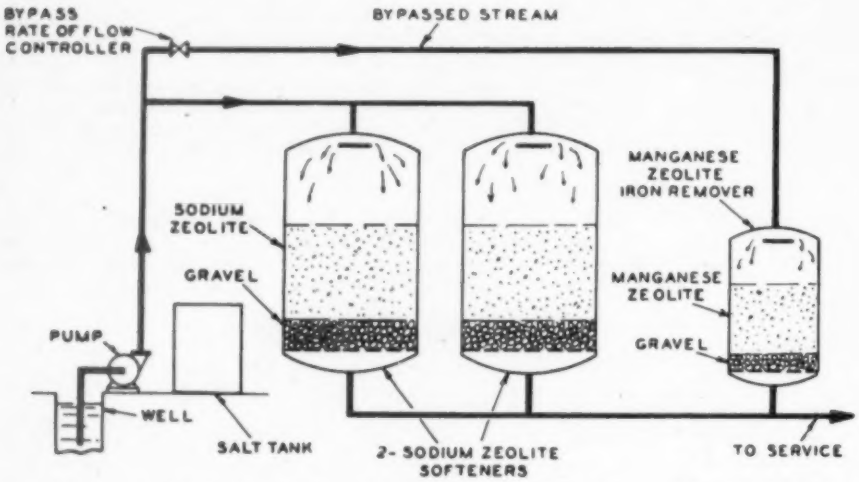


Iron Removal System Providing Flocculation.
Involving aeration, lime treatment, flocculation and clarification before filtration.

Lime is employed for the larger plants—soda ash for the smaller plants. Lime gives better results because it also has a coagulating effect. However, it also increases the hardness and as this is objectionable in many cases, soda ash is employed. The settled water is then pumped through filter equipment to either the mains direct or to storage and the mains.

Waters Containing Iron in Organic Combinations

The treatment suited to any given case of this kind will depend upon the type of organic compound present. The best treatment must be determined by experiments in the field and the laboratory. Further, the treating plant should be designed so that the pH values may be altered at will and also so that different coagulants may be added as required.



Combination Zeolite Softener and Manganese and Iron Removal Zeolite Units. Capable of producing iron free effluent of 4 to 5 grain hardness—favored in municipal installations.

Obviously, this will mean equipment for feeding various chemicals, sedimentation (and possibly double sedimentation) and filtration, plus chlorination.

Waters of Low Iron Content Where Reduction in Iron Content Should Be Below 0.1 ppm.

Manganese zeolite filters are most effective in the removal of iron where practically complete removal is desired for industrial purposes. Manganese zeolite consists of sodium zeolite treated by manganous chloride and oxidized by sodium or potassium permanganate. The manganese zeolite proper acts as an active carrier and catalytic reagent. The oxides themselves do the work of iron removal. These oxides give up oxygen to the water for the necessary oxidation reactions. They are re-oxidized by passing permanganate solution through the bed. Approximately 0.01 lb. of permanganate per thousand gallons is required for the average water. These filters are backwashed daily, but usually regenerated only at weekly intervals.

Sodium zeolite of the natural type, provided it has been correctly processed, or "Zeo-Karb" material, a carbonaceous zeolite, may be economically employed to remove iron and manganese by base exchange, at the same time that the zeolite is softening the water. When these types of zeolites are employed for iron and hardness removal by base exchange. the iron must be maintained in the *ferrous* form. Therefore,, well waters cannot be exposed to air before such zeolite treatment. The regeneration of units of this type is accomplished by the usual sodium chloride regeneration employed in zeolite softening.

Water Softening

There are five methods of water softening in general use. These are:

1. Zeolite Process—Sodium Cycle.
2. Zeolite Process—Hydrogen Cycle.
3. Cold Lime Soda Process.
4. Combination Lime Zeolite Process.
5. Hot Process.

Processes Nos. 1, 2 and 4 will reduce the hardness of the water to practically zero. Process No. 3, depending on the way it is carried out and also the composition of the raw water, will reduce the hardness from 3 to 5 grains per U. S. gallon. Process No. 5 will reduce the hardness to some figure below 1½ grains per U. S. gallon, depending upon the character of the water, the chemicals employed, etc.

Zeolite Process (Sodium Cycle)

With this method the hardness is removed by base exchange; the calcium and magnesium being retained by the zeolite while the corresponding sodium salts are found in the effluent. After the rated capacity of the zeolite to soften water to zero hardness has been exhausted, the softening capacity is restored by treating the zeolite with a solution of common salt.

As this salt solution comes in contact with the zeolite, the calcium and magnesium is removed in the form of the soluble chlorides, and its original sodium content is restored. After flushing the chlorides of calcium and magnesium, plus excess salt, to the drain, the zeolite is ready to soften a further equal quantity of the hard water.

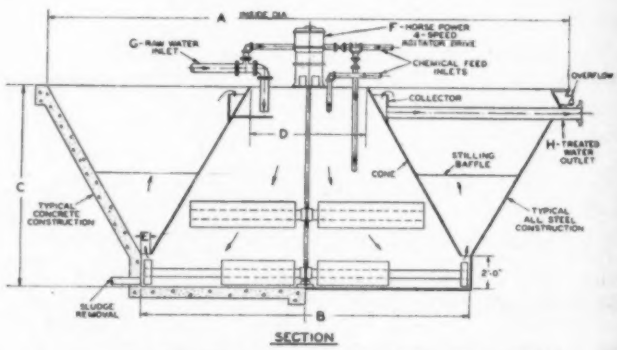
These alternate softening runs and regenerations can be repeated indefinitely, as the wear and tear on a correctly processed zeolite is negligible. Therefore, the annual cost of replacing this zeolite is correspondingly low. The effluent from a zeolite water softening plant is practically of zero hardness. As zero hardness water is either a requirement or at least desirable for most industrial processes, all of the water used in an industrial plant is usually passed through the zeolite plant. In the case of municipal zeolite plants, a zero hardness water is not required. Therefore, in such cases, enough hard water is bypassed and mixed with the zeolite softened water to yield a mixed effluent of the desired degree of hardness.

Zeolite water softeners are available to operate automatically through all cycles of operation by a combination of a motor driven multiport valve with electrical controls. Automatically, the equipment is cut out of service. backwashed, brined, rinsed and returned to service. About 90% of the more recent municipal zeolite water softening plants are of the automatic type.

Zeolite Process (Hydrogen Cycle)

In this process of water softening, a carbonaceous type of zeolite is employed. It is of especial value in softening waters of a high bicarbonate content, as the bicarbonates, of sodium, calcium, or magnesium, are replaced by carbon dioxide and water; the base being retained by the zeolite.

The carbon dioxide may then be removed by passing the softened water through a degasifier (bubbling) type of aerator. This process, therefore, in a very simple manner practically completely removes bicarbonates of all kinds.



Section Through the Spaulding Precipitator. The treated water is mixed with sludge (center) and rises upwards through the sludge blanket to the surface overflow.

At the end of the softening run, the carbonaceous zeolite is regenerated by treating it with a dilute solution of sulfuric acid. This restores the hydrogen content of the zeolite and simultaneously removes the bases in the form of soluble sulfates. These,

plus the excess of acid, are then flushed out to the drain, after which the zeolite is ready for the next softening cycle.

Cold Lime Soda Process

In this process, as carried out in the conventional type of equipment, the raw water is treated with regulated dosages of lime and soda ash. The bulk of the hardness precipitated by these chemicals, is then settled out in a settling tank having a detention period of at least 4 hours.

It is then either recarbonated and filtered or filtered and recarbonated. As usually carried out, the effluent so produced has a hardness of 5 grains per gallon.

In the relatively newer Spaulding Precipitator type of equipment, the treated water is brought into intimate contact with suspended sludge. This suspended sludge acts to produce a more stable effluent in a much shorter period of time.

In practice, it has been found that the Spaulding Precipitator requires only a one hour detention period and that the reduction of hardness is so complete that recarbonation is either carried out to a very slight extent or eliminated.

Combination Lime Zeolite Process

In the combination lime zeolite process of water softening, the bicarbonate hardness is reduced by treatment with lime. The lime treated water is then recarbonated, filtered and then passed through zeolite water softeners.

The net effect is that the lime treatment removes the bulk of the bicarbonate hardness and the subsequent zeolite treatment removes the non-carbonate hardness plus any residual bicarbonate hardness. In many cases, it has been found economical to employ this combination type of treatment because of the savings effected in the lower cost for salt vs. soda ash required per 1,000 grains of hardness removed.

For industrial processes or boiler water, all of the lime treated water is passed through the zeolite water softeners. Incidentally, when *any* water is used for boiler feed, it is important to give consideration to supplementary treatment so that the final reedwater will conform to modern power plant practice, as prescribed by the ASME. For municipal water supplies, only the requisite portion of lime treated water, required to produce a 4 to 5 grain per gallon hardness in the mixed effluent, is shunted through the zeolite water softening equipment and again joins the lime softened portion.

The hot lime soda process of water softening is carried out by adding carefully regulated dosages of lime, soda ash and/or

Hot Lime Soda Process

other chemicals to the raw water, after heating it to a temperature at or near the boiling point. Since the high temperatures employed speed up the chemical reactions, a detention or settling period of only one hour is required. (This statement indicates the value of the Spaulding Precipitator which requires no heat input.)

The settled water is then filtered through filter beds of non-siliceous material. Depending on the excesses of chemicals used, the hardness of the effluent varies from as low as 1½ grain per gallon down to a fraction of a grain. As this process must be carried out hot, its application is obviously practically limited to the production of boiler feed waters.

* The content of this article is in part derived from a paper read by the author before the Michigan Section of A.W.W.A. and Michigan Conference on Water Purfication meeting jointly.

MUD-BALL AND HARD-SPOT BREAKER

By HOMER W. SCHUMPERT

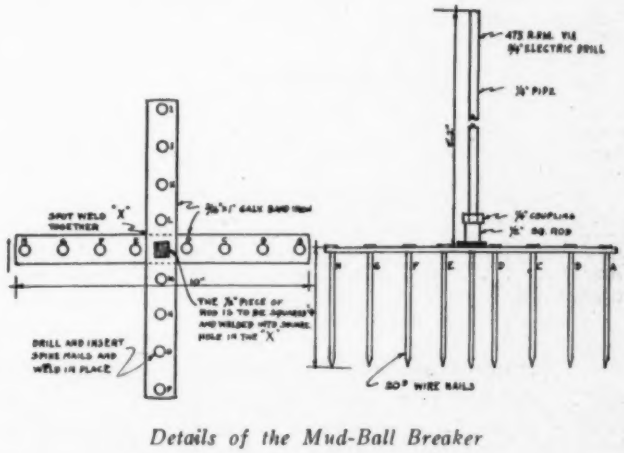
Superintendent of Water, Light and Sewage, Newberry, S. C.

Like many other plants, our filtration plant at Newberry has been troubled with mud-balls and hard-spots in the sand beds.

After trying many schemes and devices, that to be described seems to be of sufficient value to justify its publication.

The "Mud-Ball Breaker," as we call it, is here sketched. It is made from two 10-in. pieces of cross-arm bracing, for electric-line poles, welded in the form of a cross and attached to a shaft of ¼-in. steel pipe. The "tool" is turned by a light weight hand motor such as is used for electric hand-drills.

Through the pieces of bracing (1 in. wide by 10 in. long by 3/16 in. thick) are drilled holes to take 20-penny nails and a square hole (½ by 1.2 inches) is cut at the center of the cross (see sketch). The nails are welded in at their heads and the strips of bracing are spot-welded together at the center. A 2-in. piece of ½-in. steel rod is squared at the end and welded into the square center hole. A coupling and reducer connect the rod and the shaft of ¼-in. pipe. This shaft, 2 ft. long, fits into the chuck of the standard ¼-in. electric hand-drill which has a free-speed of 475 r.p.m.


475 R.P.M. VIX ¼" ELECTRIC DRILL
¼" PIPE
SHOT WELD "X" TOGETHER
¼" COUPLING
¼" SQ. ROD
DRILL AND INSERT SPIKE NAILS AND WELD IN PLACE
20P WIRE NAILS

Details of the Mud-Ball Breaker

Using the Filter Wash Tool

The water level is lowered in the filter until only 1 or 2 in. stands above the filter bed. Then the operator plugs in the cord of his tool (drill) and climbs down into the filter troughs. He starts the tool rotating at the 475 r.p.m. speed and proceeds to attack the mud-spots with it for about 6 minutes, employing a churning (up and down) motion of the whirling head. Then the filter is washed as usual.

We tried experiments thinking it possible to improve this device, but in the end we believe the sketched tool, as simple as it is, does the best job without the "improvements." When the spinning cross arms strike a wall the tool merely bounds away without damage. The whole assembly is light, inexpensive, and (most important) it does the job.

[Mr. Schumpert comments by letter: "If you do not believe that the job is easily and effectively done, then just try it yourself."—Ed.]

WILSON CHEMICAL FEEDERS, INC.

Manufacturers of Pulsafeeders for
Chemical Solution Water Treatment

BUFFALO, NEW YORK, U. S. A.

THE WILSON "PULSAFEEDER"

is a positive displacement, pump type chemical solution feeder; designed primarily for the feed and accurate control of both corrosive and "hard-to-handle" chemicals.

Basically PULSAFEEDER is in the family of accurate piston pumps. However, it is also equipped with a diaphragm to actually separate the chemical solution being pumped, from all operating or moving parts. No packing glands are used, and the diaphragm has no mechanical connections.

Low pressure models of PULSAFEEDER handle solutions against pressures up to 200-lbs. per sq. in. High pressure models are good up to 1500-lbs. per sq. in. Sizes are available up to 400-gals. of solution per hour.

CHEMICAL SOLUTION WATER TREATMENT

HYPO-CHLORINATION

The PULSAFEEDER was originally designed for use with either calcium or sodium hypochlorite. A complete treatment system is available for either manual, semi-automatic or fully automatic operation. Feeds all concentrations; supplies up to 500,000 gals. of water per day.

COAGULATION

Accurate control of coagulation chemicals for water or sewage filtration, employing use of aluminum salts, iron salts and the like. Units available in capacities up to 400-gals. per hour.

pH CONTROL

PULSAFEEDER's principal of chemical solution isolation allows for feed of all concentrations of acids and alkalis. Guarantee of not more than ⅛ of 1% feed variation assures accurate pH control.

CALGON FEEDING

Scale prevention, iron control, corrosion control all handled expertly by PULSAFEEDER. Hundreds of units are in use in water supplies of all types and sizes.

ODOR, TASTE AND COLOR CONTROL

Problems involving odor, taste and color control are all within the scope of WILSON PULSAFEEDERS. Write us for recommendations.

OTHER USES

PULSAFEEDERS are also adapted to many processing problems, food equipment sterilization, boiler chemical feed, automatic blending operations, and other accurate proportioning problems.

Manual and Fully Automatic PULSAFEEDERS

The various PULSAFEEDERS use either electric motor, gasoline engine, water or air motor drives, and are controlled by water meters of all types if flow-proportional feed is desired. The types below represent a complete line of chemical water treatment apparatus.

MANUAL

Type DES—
Electric motor driven simplex model, for feed of a single chemical solution.

Type DED—
Electric motor driven duplex model, for feed of two solutions. Used widely for chloramines.

Type DET—
Electric motor driven triplex. Generally used for hypochlorite, soda ash and alum. For feed of three solutions.

Type DEQ—
Electric motor driven quadruplex. For feed of four solutions simultaneously, each feed independently adjustable while in operation.

Type DEG—
Emergency portable model for water sterilization. Feeds against 200-lbs. per sq. in. Capacity 300-lbs. chlorine per 24 hours.

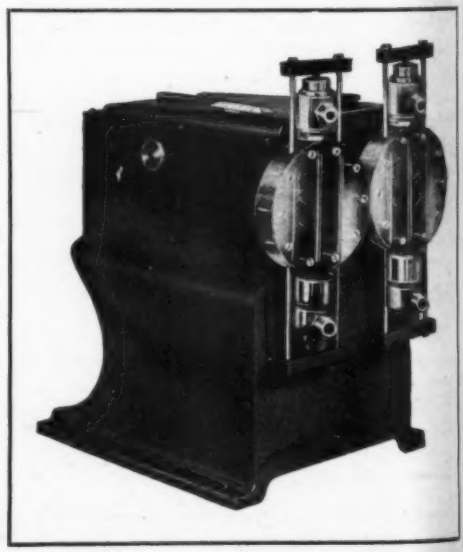
AUTOMATIC

Type MC-DES—
Electric motor drive, meter controlled. Applicable to all liquid meters. Single and multifeeders.

Type MC-DS—
Water or air motor drive, meter controlled. Applicable to all meters. Single and multifeeders.

Type MC-WD—
Water or air motor powered, meter controlled, marine type. For installations aboard ship.

Type SP—
Flow-proportional, pressure differential feeder for operation with orifices, flow nozzles or venturi. Operates on 1" water differential and up.



GRAVER TANK & MFG. CO., INC.

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GRAVER WATER CONDITIONING EQUIPMENT

Aerators — Chemical Feeders — Clarifiers — Chlorinators — Water Filters — Taste and Odor Removal Filters — Iron Removal Filters — Oil Removal Filters — Swimming Pool Water Filters and Equipment — Filtering Material — Proportioning Equipment — Lime and Soda Hot or Cold Process Softeners — Zeolite Water Softeners

GRAVER HOT PROCESS DEAERATING WATER TREATING SYSTEM

This equipment removes scale-forming ingredients and corrosive dissolved gases from the boiler water supply, rendering the water suitable for use in high pressure boiler plants. Supplied as a part of the system are chemical feeders and proportioners, filters with non-siliceous filtering material and control valves, and auxiliary chemical feeders for after-treatment. Chemical feeders and proportioners are automatically controlled by the flow of water into the treating plant. Chemical charges can be varied to suit variations in quality and quantity of incoming raw water.

GRAVER ZEOLITE WATER SOFTENER

This type of equipment softens extremely hard water to zero hardness as determined by standard soap test. When water of zero hardness is not desired, blending with raw water automatically produces treated water of any desired degree of hardness.

Complete removal of dissolved solids from water supply for boiler feed purposes can be accomplished by Graver ionic exchange carbonaceous zeolite water softener.

This equipment can be furnished for manual operation using individual gate valves, or for semi-automatic operation whereby the various cycles are electro-hydraulically controlled by a push button, or entirely automatic operation, where all of the operating cycles are controlled automatically.

GRAVER CONTINUOUS LIME AND SODA WATER SOFTENERS

This equipment consists of settling and reaction tanks; chemical feeders, either solution or dry type; recarbonators for recarbonation of treated waters; filters, either pressure or gravity type; and all accessories for a complete system.

GRAVER WATER FILTERS

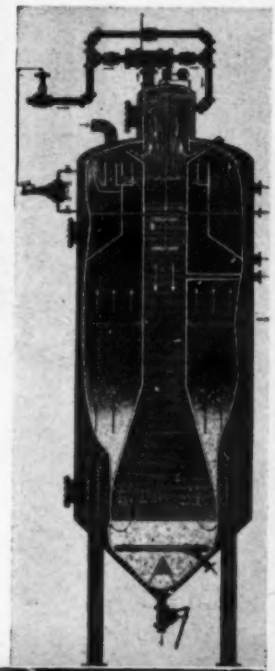
Graver Water Filters, either vertical or horizontal type, can be built in any convenient size. The filters are furnished complete with the necessary filtering material and all piping, fittings, and control valves arranged for filtering to service, backwashing to sewer, and rinsing to sewer. Graver Water Filters insure a supply of uniformly clear, filtered water that will meet the most rigid requirements.

The hundreds of Graver Water Filters in use today in industries, institutions, and municipalities have demonstrated their exceptional efficiency as well as their low cost of operation and maintenance.

GRAVER SWIMMING POOL FILTRATION

Graver can supply complete filtration, recirculation, and sterilizing systems for the conditioning of the swimming pool water to meet the most rigid public health requirements. A complete Graver swimming pool system consists of pressure or gravity filters for the filtering of pool water, coagulant feeders, recirculating pumps, hair strainers, chlorinators, vacuum cleaners, pool fittings, water heaters, and pool accessories.

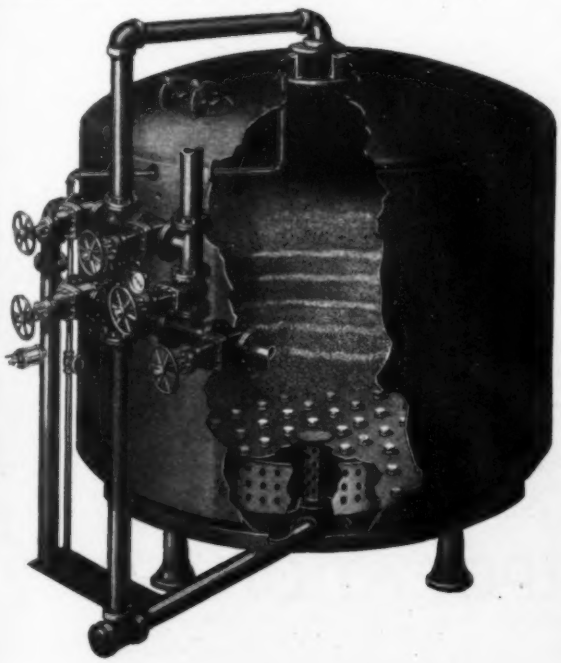
Graver engineers will gladly discuss your water conditioning problems with you and cooperate with your engineers in designing the equipment to meet your requirements.

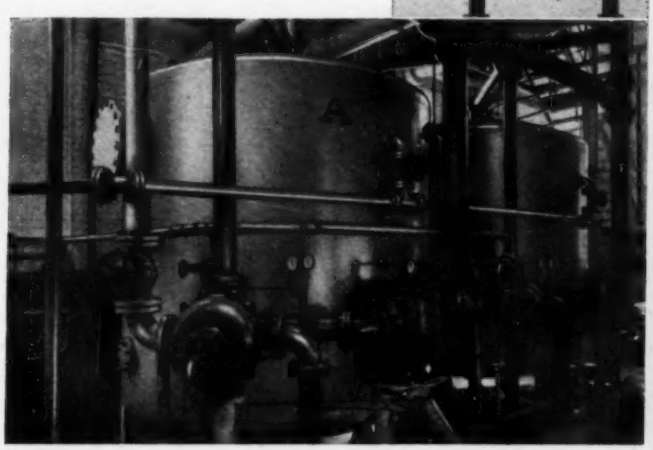


Right—Graver Hot Process Water Softener with Deaerating Equipment.

Left, below—Graver Water Filter.

Right, below—Installation of Graver Zeolite Water Softeners.





See Our Advertisement on Sewage Treatment Equipment, Page R-174

Save With Ferri-Floc

FERRIC SULPHATE

FERRI-FLOC is the ferric coagulant that is today solving water and sewage problems throughout the United States. In actual plant operations **FERRI-FLOC** is proving most satisfactory for use under widely varying conditions.

In water treatment, the use of **FERRI-FLOC** varies from simple coagulation at normal pH's to softening at high pH's, and color removal at very low pH's.

In sewage plants, **FERRI-FLOC** is being used at high pH values for treatment of concentrated laundry wastes, at extremely low pH values for slaughter house wastes, and at practically all intermediate pH's for treatment of domestic sewage, milk wastes, canning plant wastes, acid wastes, and a multitude of others.

The purity of **FERRI-FLOC** has not only been maintained during present adverse conditions but has actually been improved.

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Take advantage of modern plant research and findings: let FERRI-FLOC solve your water or sewage treatment difficulties. Ask Tennessee Corporation's Technical Staff to help you solve your specific problems, or write for case histories of plants with problems similar to yours.

TENNESSEE CORPORATION

ATLANTA, GEORGIA LOCKLAND, OHIO

MANGANESE REMOVAL

Experiences at Durham, N. C.

By ROBERT S. PHILLIPS
Chief Chemist, Water Department
Durham, N. C.

THE City of Durham receives its raw water from Lake Michie on Flat River, approximately nine miles from the city. This lake will impound almost five billion gallons of water, a sufficient amount to provide the city with water even during a period of prolonged drought.

The raw water is pumped to a storage reservoir at the treatment plant through 24-in. and 20-in. mains. The storage reservoir is of sufficient capacity to hold nearly a week's supply at peak demand.

Occurrence of Manganese

The source of manganese in the Durham supply seems to be the manganese-bearing rock and clay forming the bed of the impounding lake. Long periods of impounding, due to lack of rainfall, and proper conditions for anaerobic decomposition causes relatively large amounts of manganese to be released to the raw water, the quantities being revealed in Table I.

TABLE I

Year	Percentage Normal Rainfall (Annual)	Manganese in Impounded Water (ppm) Avg.	Max.	Month of Maximum Occurrence
1935	84	0.05	0.23	August
1936	121	0.04	0.19	September
1937	115	0.03	0.07	October
1938	98	0.10	1.20	September
1939	117	0.05	0.18	November
1940	86	0.10	0.75	August
1941	54	0.27	1.40	August and October

The tabulated data reveals the occurrence of manganese may reach a maximum at any time from mid-summer to late fall. Also, unless the rainfall is not considerably above normal the manganese content may become quite serious. This is especially true when the rainfall in two consecutive years like 1940 and 1941 is far below normal. Even with normal rainfall (annual) the manganese content may reach high levels, as in 1938 when the last six months of the year were relatively dry.

Removal of Manganese by the Permanganate Oxidation Method

Since 1933 we have been removing manganese by the use of the Permanganate Oxidation Method. This method over the entire period of years has accomplished the desired results producing an effluent water low in manganese. For purposes of comparison later in this article the results of this treatment are given for August 1941 in Table II.

TABLE II
PERMANGANATE OXIDATION METHOD
(AUGUST 1941)

	Parts per million Max.	Min.	Avg.
Raw Water, Manganese, (Mn)	1.20	0.60	0.82
Filtered Water, Manganese, (Mn)	0.12	0.03	0.07
Dosage, Potassium Permanganate	2.22	1.73	1.95

Although good results were indicated by the use of the lime-alum method, it would have necessitated major changes in our lime feeding and somewhat higher alum dosages would have been required. In addition it was indicated that approximately 50 per cent of the oxidized manganese would precipitate in the raw water storage reservoir, for which an adequate removal system is not provided.

Laboratory samples of raw water coagulated with ferric sulfate, $Fe_2(SO_4)_3$, had previously shown that approximately the same dosage of this chemical was required as with alum for efficient coagulation. The soluble iron in filtered samples was quite low (.05-07 ppm.). Hopkins,[1] Black[2] and Willcomb[3] report the successful removal of manganese using iron salts and lime providing the pH of coagulation is kept above 9.0.

TABLE IV
RESULTS JAR TEST
Manganese Removal with Ferric Sulfate and Lime

Raw Water Data

Turbidity	30 ppm.	Free Carbon Dioxide	8 ppm.
pH	6.7	Dissolved Oxygen	4.6 ppm.
Alkalinity	24 ppm.	Manganese (Mn)	0.7 ppm.

Chemical Dosages, ppm.

Jar No.	$Fe_2(SO_4)_3$	$Ca(OH)_2$*	pH	Manganese in Filtrate, ppm.
1	25	15	7.0	0.70
2	25	20	8.2	0.70
3	25	25	8.9	0.12
4	25	30	9.2	0.04

*Note—Lime added just after floc began to form.

It will be noted that the required dosage of $KMnO_4$ was slightly more than twice the manganese content of the raw water. This ratio is typical of our experience for the past eight years when the method was used.

Early in 1941 it became evident that Potassium Permanganate crystals would not be available for use in quantities required for water treatment. This chemical, therefore, became for us the first casualty of World War II and it was necessary to seek another method of removing manganese.

Methods Put to Laboratory Test

Experimental work was immediately begun in an attempt to find a satisfactory substitute for the Permanganate Method.

As pointed out, we have a relatively large raw water storage reservoir at the treatment plant with a retention period of a week or more. An experiment was set up to determine the time required to oxidize the manganese under the influence of a relatively high pH, and to find out if the oxidized manganese could then be removed with ordinary alum flocculation.

Each of seven large bottles of lake water was dosed with hydrated lime (23 ppm.) to an initial pH of 9.3, and allowed to stand at room temperature. Each day a portion of the settled water was carefully siphoned off from one bottle. A manganese determination was made on the siphoned-off sample before treatment. Another portion of the settled sample was coagulated with 40 ppm. alum. The jar was then allowed to settle three hours, after which the supernatant was filtered (No. 12 filter paper used, discarding the first 200 mls. filtrate) and another manganese determination made on the filtrate. The results shown in Table III were obtained.

The series of jar tests using the commercial ferric sulfate "Ferrisul" and lime were set up. The dosage of the iron salt was kept constant while the lime added was varied. Each sample was allowed to mix and settle for the same periods as would be the case under plant conditions. After settling, the water was filtered and the manganese content determined.

This same test was duplicated many times and indicated that highly satisfactory removals could be expected with ferric sulfate and lime providing the pH of coagulation was kept sufficiently high. This confirmed the work of others.

The mechanism of removal of manganese by this method is apparently complicated and not very well understood. It appears to involve both chemical and physical actions. Wilcomb[3] suggests that the action takes place in two ways: first, due to the alkali

TABLE III
LABORATORY RESULTS MANGANESE OXIDATIION WITH HYDRATED LIME

Contact Time with $Ca(OH)_2$, days	0	1	2	3	4	5	6	7
pH	9.3	9.1	9.1	8.9	8.9	8.7	8.6	8.5
Turbidity, Settled Water, ppm.	60	40	35	35	35	30	30	25
Manganese, Settled Water, ppm.	0.90	0.90	0.60	0.70	0.60	0.60	0.45	0.50
Manganese, Coag. and Fltd., ppm.	0.60	0.25	0.15	0.18	0.12	0.08	0.06	0.04

TABLE V
SUMMARY OF RESULTS WITH THE USE OF FERRIC SULFATE 1941-1942, DURHAM, N. C.

	1941				1942			
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	July	Aug.
CHEMICAL DOSAGES (ppm.)								
$Fe_2(SO_4)_3$	27.1	24.2	25.0	24.0	19.7	19.4	39.8	38.2
$Ca(OH)_2$ (Primary)	27.7	26.9	24.2	22.3	6.9	0	35.9	33.3
Primary Chlorine	0.90	0.83	0.61	0.52	0.62	0.72	0.83	0.86
Ammonia	0.16	0.16	0.12	0.11	0.14	0.16	0.21	0.20
Carbon	2.0	3.2	3.7	3.9	4.8	2.5	2.8	3.9
RAW WATER (Averages)								
Temperature, °C.	21.5	20.1	14.5	9.2	6.0	5.9	20.2	24.1
Turbidity, ppm.	24	16	14	15	12	12	157	173
Hardness as $CaCO_3$, ppm.	20	20	20	21	20	21	14	15
Total Alkalinity, ppm.	25	27	24	24	24	23	15	15
Free Carbon Dioxide, ppm.	6.3	4.7	4.5	4.4	3.1	3.4	7.6	6.9
pH	6.9	6.9	7.0	7.1	7.2	7.2	6.6	6.7
Manganese (Mn), ppm.	0.70	0.68	0.31	0.16	0.09	0.11	0.71	0.53
Iron (Fe), ppm.	2.5	1.3	1.2	1.3	1.1	0.9	7.4	3.1
pH of Coagulation	9.0	9.1	8.9	8.8	7.1	6.1	9.1	8.9
TREATED WATER (Averages)								
Temperature, °C.	22.7	20.4	14.4	9.3	6.2	5.8	23.3	24.4
Turbidity, ppm.	0.10	0.10	0.11	0.08	0.09	0.07	0.26	0.27
Hardness as $CaCO_3$, ppm.	48	47	43	41	37	37	49	49
Total Alkalinity, ppm.	37	40	33	31	28	27	27	26
Phenolpthalein Alk., ppm.	5	10	7	3	3	4	5	4
pH	8.9	9.1	9.1	8.7	8.5	8.6	9.0	8.7
Manganese (Mn), ppm.	0.03	0.04	0.02	0.01	0.05	0.07	0.03	0.02
Iron (Fe), ppm.	0.08	0.05	0.04	0.04	0.04	0.04	0.09	0.10

present the oxidation is rapid and the oxidation products are absorbed by the ferric hydrate floc, and secondly that the manganous hydroxide itself absorbs colloidal manganese particles. The largest absorption apparently is accomplished by the ferric flocs due to the fact that they predominate.

Earlier experiences at Albany and Providence had also demonstrated that ferric sulfate could be successfully and simply used as a coagulant for moderately colored soft waters containing manganese. We therefore made arrangements to employ ferric iron coagulation in Durham.

"Ferrisul" Coagulation Adopted

The commercial product used was Monsanto's "Ferrisul." This chemical is of uniform granular size feeding well in ordinary dry chemical feeders. It comes in multi-walled paper bags of 100 lbs. which can be handled readily and stored without caking. A 15-gallon crock is used as a dissolving pot, into which the ferric sulfate is fed The crock receives a constant measured flow of water through a "Rotameter," a simple and inexpensive device for measuring low flows. The water and chemical are agitated vigorously with a mechanical agitator to insure more rapid and complete solution. The solution of ferric salt is picked up by a glass eductor and forced through an ordinary ¾-in. garden hose to the mixing chamber. The entire cost of equipping one dry feeder to feed this chemical was approximately $150.00. Very little trouble is experienced in dissolving the ferric salt and corrosion difficulties have been at a minimum.

The lime is applied to the water *after* approximately two minutes of mixing, at which point the iron floc has already started to form. After a further mix of about six minutes the water enters the settling basins.

The use of ferric sulfate was begun September 11, 1941 and continued until February 17, 1942. Again on June 28, 1942 it was employed and has continued in use to the present time. The results of these periods are summarized in Table V.

Comparing the Permanganate and Iron Methods

Comparative data on the two methods which have been used locally for manganese removal are interesting. The Permanganate Oxidation method is more costly and on the whole will not remove the manganese quite as completely as the iron treatment has. On the other hand with the ferric sulfate and lime method the hardness is higher in the finished water, due to high lime dosages required. And, at times the water must be coagulated above the Calcium Carbonate equilibrium point. Under this condition manganese removal is more complete and consistent.

TABLE VI
Comparison of Chemical Costs of Permanganate Oxidation Method and Ferric Sulfate Method

	$KMnO_4$ Method	$Fe_2(SO_4)_3$ Method
M.G. Treated	274.121	339.779
Alum, lbs.	58,200	0
Ferric Sulfate, lbs.	0	67,600
Lime, lbs.	40,200	73,950
Permanganate, lbs.	3,850	0
Chlorine, lbs.	2,508	1,908
Ammonia, lbs.	353	398
Total Cost Chemicals	$1,993.01	$1,617.19
Cost per M.G.	$7.27	$4.76

In order to give a fairly true evaluation to the relative cost of the two methods the months of August, September and October 1940 and 1941 were selected. Throughout this period both methods were used and conditions were comparable.

The Matter of pH Values

Experience throughout 1941 and 1942 in periods of manganese removal with ferric sulfate has indicated that it is not always necessary to carry the pH of coagulation above 9.0 Satisfactory manganese removals (less than .05 ppm. in filter effluent) have been obtained with the pH as low as 8.5. Rather the pH of coagulation necessary for good manganese removals will vary between 8.5 and 9.3 depending on the concentration of manganese in the raw water. The higher the manganese content in the untreated water the higher the pH of coagulation must be carried to achieve satisfactory results. This is important where industrial users require a finished water in which the calcium hardness must be kept at a minimum.

TABLE VII
Showing the Lowest pH of Coagulation to Reduce Manganese Content in Filter Effluent to .05 ppm. or Less with Various Concentrations of Manganese in Untreated Water.

pH of Coagulation	Manganese in Untreated Water ppm.
8.5	0.20
8.6	0.30
8.7	0.40
8.8	0.55
8.9	0.65
9.0	0.75
9.1	1.00
9.2	1.20

In manganese removal the Ferric Sulfate Method works very well providing the soft water treated is only moderately colored. This was true in our case during 1941. During the current season, however, the raw water contained a relatively high color—200 to 300 ppm.—in addition to high concentrations of manganese and turbidity. When the water was coagulated at a high pH for manganese removal the color of the filter effluent was 15-20 ppm. When the pH of coagulation was lowered to the acid range all of the color was removed but the manganese content remained unaffected. The choice was clear; we chose to allow the lesser of the two evils to remain in the finished water. We, therefore, delivered a water having a color four to five times its normal content.

In the meantime laboratory experiments were conducted to remove color and manganese simultaneously with the ferric sulfate method.

Various well-known color removal methods were tried in the laboratory without success. Relatively large dosages of carbon were added to the water along with the coagulants; activated carbon was suspended in the settled samples; bleaching clays with

the coagulants was tried, and sodium aluminate was tried in conjunction with the iron salt and lime. None of these methods gave positive results.

Relatively high dosages of chlorine offered the first possibility of success. The chlorine was added to the water immediately following the introduction of the coagulants, allowing the water to mix the normal time and then settled for a period of five hours. The settled water was then decanted and filtered. Color determinations were made on the filtrate. Chlorine determinations were made on the settled water.

TABLE VIII

Jar Test to Determine the Effect of High Dosages of Chlorine on Color.
Date: July 19, 1942
Raw Water Color: 250 ppm.
(Results in parts per million)
Chemical Dosages

Jar No.	Ferric Sulfate	Lime	Chlorine	Residual Chlorine 5 hours	Color Filtrate
1	40	40	0	0.00	17
2	40	40	2	0.65	15
3	40	40	4	0.75	10
4	40	40	6	0.80	5
5	40	40	8	1.10	3
6	40	40	10	2.25	0+

The above results are typical of many duplications of this experiment. Dechlorination after contact period did not affect the color.

Our plans now are to provide the necessary equipment for feeding the larger dosages of chlorine followed by dechlorination. This method for color removal in conjunction with manganese removal by ferric coagulation will be put into operation just as soon as the chlorine gas and equipment becomes available.

Summary

1. The occurrence of manganese at Durham is governed principally by the amount and distribution of rainfall throughout the entire year. The maximum concentration of manganese in the raw water may occur at any time from mid-summer to late fall.
2. Eight years of experience shows that good manganese removals can be achieved with the Permanganate Oxidation Method. Crystals of Potassium Permanganate are not available at present for water treatment.
3. Plant results with the ferric sulfate and lime method for manganese removal indicate that it is reliable and highly efficient on moderately colored soft waters. The cost of this method is considerably lower than the Permanganate Oxidation Method.
4. Where soft waters are highly colored, difficulty may be encountered in removing both color and manganese simultaneously by the ferric sulfate method. High chlorine dosages along with coagulants make possible the removal of color and manganese at the same time.

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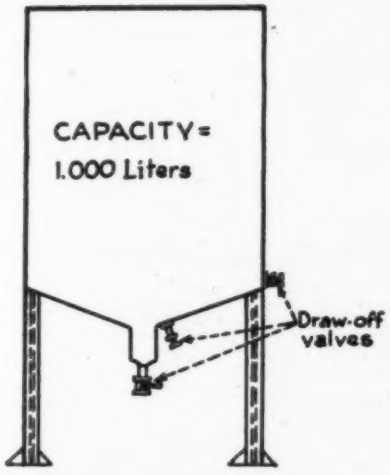
THE DETERMINATION OF SAND IN WELL WATER

A sample of water is collected in a two (2) liter bottle and is given a rotary motion so as to move the sand toward the center of the bottom of the bottle and to form a disk. Standards are prepared from a similar sand by placing in wide mouth bacteriological bottles, of 125 ml. capacity, measured amounts that correspond to 1, 3, 5, 10, 15, 25, 50, 100 and 200 parts per million by volume in two (2) liters of water. Water is then added to about half the height of the bottle. For standards of 300, 400, 500 and 600 p.p.m. it is preferable to use bottles of 250 ml. The standards are given a rotary motion to obtain a disk of sand in the center of the bottom of the bottle and the disks are then compared with the disk on the bottom of the bottle of the two (2) liter sample of water. It is essential to select bottles with a smooth, flat bottom of clear glass. There is no difficulty in determining whether the sand in a two (2) liter sample is more or less than one (1) part per million by volume.



TANK
FOR DETERMINATION OF SAND

During a two-year period about 4,500 daily routine determinations of sand in the water pumped from 16 deep wells of the Maracaibo water works were made and reported weekly. Following the removal of sand that accumulated in the bottom of the wells during several months of pumping, tests have been made on the water pumped to waste to determine when the sand content decreased to 5 p.p.m. before the water was allowed to enter the collecting system. A routine determination is made of the amount of sand in all samples of water from deep wells that are delivered to the laboratory of the Ministry for physical-chemical analysis.

For the more accurate determination of the amount of sand a cylindrical steel tank, of a capacity of 1.000 liters, with a conical bottom may be used. Valved outlets, as shown in the illustration, should be provided. The bottom of the tank should be elevated above the ground by legs attached to it or by an independent frame of steel angles so that a small pail or other receptacle may be placed under the lowest outlet.

The tank is filled with the water that is being pumped from the well and is allowed to settle for 30 minutes or longer, if the sand is very fine. The upper outlet is then opened to draw the water down to the cone-shaped bottom. The remaining water is then stirred with a rotary motion to move most of the sand into the small cylinder on the bottom of the tank. The water in the cone above the cylinder is then drawn off slowly through the outlet that is provided. A suitable receptacle, preferably white enameled, is then placed under the cylinder and the lowest outlet opened to discharge the water and sand. The bottom of the tank should be flushed with small amounts of water to remove any grains of sand that may remain.

After the sand has settled to the bottom of the receptacle most of the water may be siphoned off and the sand washed into an Imhoff cone of 1.0 liter capacity, graduated from 0 to 1.0 ml. in 0.1 ml. divisions. A cone with a sharp tip is preferable as more accurate readings of volumes less than 1.0 ml. may be obtained. The volume of sand should be read while it is submerged in water, in order to obtain the true volume, and then converted into equivalent parts per million by volume.

It is preferable to employ a tank with a capacity of 1,000 liters, not only to obtain a satisfactory amount of sand but also a direct reading from the Imhoff cone as 1.0 ml. of sand equals 1.0 part per million by volume. The interior of the tank should be kept well painted to prevent the addition of particles of rust to the sand and it should be thoroughly cleaned before a test is made.

Consultant, Department of Hydraulic and Sanitary Works, Ministry of Public Works, Caracas, Venezuela, S. A.

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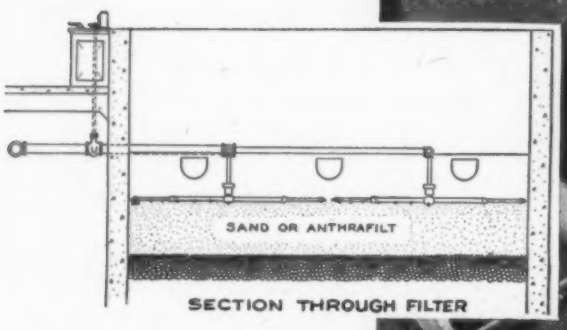

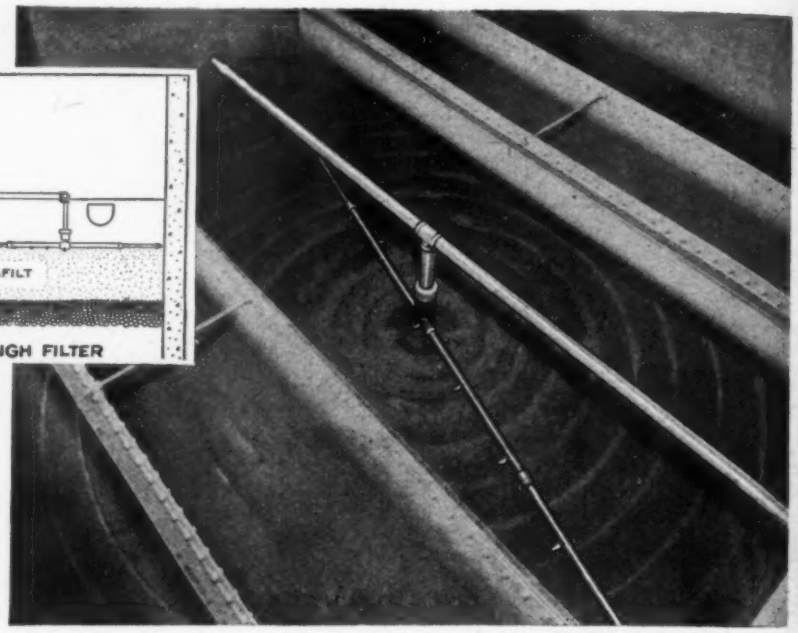

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FILTER WASHING

Some Observations on and Results with Methods Old and New

By H. J. KRUM, Supt. of Filtration and I. M. GLACE, Consulting Sanitary Engineer
Allentown, Pa., and Harrisburg, Pa.

THE authors of this paper, although having no official connections, have nevertheless cooperated for years on the solution of the many difficulties incident to the proper maintenance of public water supplies and the collection and disposal of sewage, including certain research and operating problems. The care of filters, naturally, has been one of the matters considered.

This association has been unusually beneficial to both authors and the more effective, it is felt, because one author (Krum) has had available a large and well equipped laboratory for chemical and bacteriological studies and, as chief operator of a ten million gallon rapid sand filter plant as well as several smaller swimming pool filters, has been able to install for experimental purposes many devices of varying kinds, and to put into practice a number of improved operating procedures.

Although the authors confess to differences of opinion on some of the practices of the profession, they find themselves in complete agreement on the desirability of better facilities for the cleansing of the media of filter units, and on the efficiency of the socalled surface-wash.

The data and conclusions presented herein represent a consolidation of ideas and opinions based on detailed research at one plant and on general observations at plants over a wide area.

Past Practices

For the sake of clarifying this discussion, and in an attempt to indicate briefly the struggle of the profession to solve this knotty problem of filter operation, the historical outline which follows is cited to show approximately the time periods in which certain designs and practices have been popular in the water works field:

—Prior to 1910—

In circular tub filters; with false bottoms, pipe laterals, a variety of types of strainer heads and, commonly, revolving fixed rakes, with "low" wash water rates of 8" to 12" rise per minute.

1910 — 1920

In rectangular concrete units; with slightly increased wash water rates, and frequently air wash as an auxiliary.

1920 — 1930

As in 1910-1920, but with "moderate" rates of wash up to about 30" rise, and with perforated lateral pipes and deeper gravel beds for better distribution.

1930 — 1940

As in 1910-1920, but with "high" rates of wash up to 48" rise per minute, a variety of filter bottoms, many of a nonmetallic character, and frequently false bottoms to replace manifolds and laterals.

Surface wash was introduced as an auxiliary to the bottom wash, with either fixed or revolving piping at the surface of the medium for such purpose. The introduction of porous plate filter bottoms, eliminating the gravel bed.

Seemingly most of the difficulties in filter washing began with the advent of the rectangular concrete box filter. This period coincided with the abandonment of the circular wooden-tub type filter and mechanical rakes.

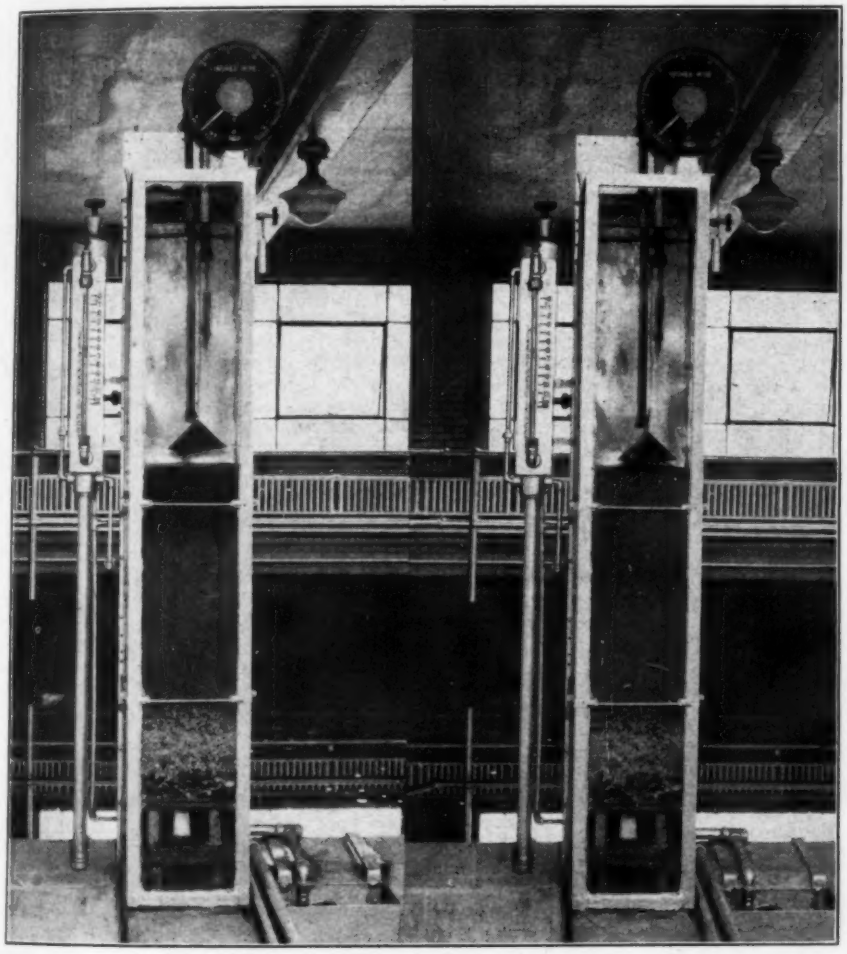
The time periods indicated are, perforce, only approximations and considerable overlapping naturally occurs in any such classifications. As for instance, perforated pipe laterals were used as early as 1905, at the Harrisburg, Pa., works.

Mention should be made of the use of slat-bottomed units which, generally, have never been accepted by the profession because they seem to violate one of the basic principles of design; that is, the production of a uniform head at the base of the strainers, or other openings through restricted orifices.

Mention might be made, also, of the use in a number of plants of fine mesh screens, installed between the top of the gravel layer and the sand bed to prevent "upsetting" of the gravel; a condition which, it is not generally recognized, exists to some extent in practically all units not in some way protected against disturbance. This point in the filters—the junction of the sand and gravel—might well be classed as the "danger line," since a serious upset at this junction of the two media results finally in the failure of the bed to perform its functions and, ultimately, in the necessity for a complete and expensive overhauling of the affected unit. The seriousness of this problem brought forth the development of the porous-plate false bottom, a very promising improvement in design.

In addition to the listed methods of construction, an enormous amount of time and effort has been given to a study of the sizing and specific gravity of the filtering media, resulting, from a design standpoint, in the use of anthrafilt in many filters, and the use of coarser sands of a larger effective size.

All of this — revolving rakes, air wash,



The Allentown Experimental Filter.

Fig. 1 (left) shows the layer of coated top sand after many repeated washings at high rate bottom wash alone.

Fig. 2 (right) reveals the result of sand scour secured by surface-jet wash for only a short period.

The hanging cone is the sand bed expansion indicator developed at Allentown for indicating correct washing rates throughout the year.

false bottoms, screens as gravel retainers, "high" rates, and what not, even when combined with greatly improved mixing and coagulation of chemicals—has not resulted in the design or use of any one "best" procedure, or in the prevention of mud-balls, hard spots, and the necessity for the frequent expesive overhauling of the units; nor has it provided operators with means for maintaining a really *clean* filtering medium.

It is admitted that in some of the more carefully designed and better operated plants these interferences in filtration have been held to a minimum but so far as the water works field generally is concerned, the results are stated above.

High Wash Rates Disappointing

Of these various features of design, the so-called "high" wash rate seems to have been the greatest disappointment and the most misleading. A rise of as much as 48" per minute is exceptional but when this is expressed, as it might well be, as 4 feet per minute, the actual low velocity of such a flow can be more readily recognized. Although the actual velocities through the interstices of the expanded sand may be 2 to 3 times this stated velocity, but little sand scrubbing effect results.

The Surface Wash

Various forms of surface wash have been developed in the last half dozen years (not considering the old revolving rake in this classification) with almost universal improvement in operation.[1, 2] The development of the relatively inexpensive and easily installed Palmer Filter Bed Agitator has speeded up the trend towards such a form of auxiliary wash since it was introduced to the field in 1939, and first described by the inventor, a filter operator, in this magazine.[3]

The success of these various forms of surface wash is the result of the relatively high velocities of the jets issuing from the distributor arms, which velocities commonly reach from 50′ to 100′ per second, or 1,000 times that of the socalled "high rate" bottom wash. The tremendous scouring action of these fire stream velocities is at once apparent.

Some Allentown Observations

When Hulbert and Herring[4] first directed the attention of the profession to the importance of the degree of expansion of the sand bed in filter washing and emphasized the higher efficiency of the more viscous low temperature water, in expanding the media, the authors became interested in the importance of wash water control to secure effective bed expansion under all conditions. To this end Krum, in cooperation with the Simplex Valve and Meter Co., developed the sand expansion indicator, now used successfully in many plants. Data on these studies was first published in WATER WORKS AND SEWERAGE.[5]

For the Allentown experiments a model filter unit with glass sides was constructed. It had an effective area of one square foot and was built to full vertical scale. It was equipped with the perforated concrete Leopold bottom, a duplicate of the block originally installed in the Allentown plant. In other words, the experimental unit is an exact replica of a 12-inch square section of the full size filters—see Fig. 1.

Sand for the experimental unit was taken from one of the plant filters, using a perpendicular column of sand extending from the surface down to the gravel layer. The sand at the bottom of this column had the appearance of clean sand, but the top 8 inches was black in color and had a coating of impurities, approximating 20 per cent by weight. This experimental bed was washed repeatedly, probably 200 or 300 times, at wash rates which expanded the sand in varying degrees up to 60 per cent.

During the course of these experiments on the rate of expansion no new sand was added to the filter; nor, although the unit is equipped to receive coagulated and settled water, was such water applied to the unit. The coated condition of the top sand at the end of the repeated high rate washings in these experiments is revealed in Fig. 1. In the photograph it has the appearance of a layer of black water rather than sand.

At the conclusion of these expansion experiments a fixed jet surface wash of the Baylis type, shown in Figs. 1 and 2 as a perpendicular pipe extending downward and ending 3 inches above the top of sand bed, was installed in the experimental filter to determine whether or not the coating on the sand grains could be removed by this method of washing. The results were startling. The application of the high pressure water jets to the unexpanded sand created a violent movement in the top 8 inches of the bed. This scoured the sand so effectively that the supernatant water immediately became opaque because of the turbidity, and was black in color. After two minutes of this initial scouring of the settled bed, wash water was introduced from below and the entire bed of sand expanded 50 per cent. The resulting downward movement of the upper sand, due to the action of the surface jets, and contact with the upward movement of the lower sand due to the back wash, caused a second violent scouring, with a penetration to 18 inches below the surface. Repeated washing of the sand in the experimental unit by this method resulted in the disappearance of the black coating on the top sand, and the entire volume of sand attained the appearance of uniformly clean sand, as revealed in Fig. 2.

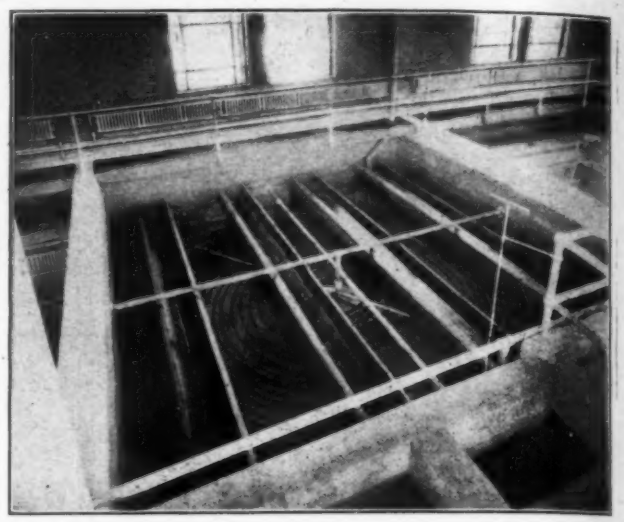


Fig. 3—One of the 1.25 M.G.D. Filters Equipped with Palmer Revolving Agitators.

This demonstration convinced the authors of the comparative inefficiency of the normal method of washing filters. Observations, in other plants have simply confirmed this conviction and further convinced us of the comparative inefficiency of the normal method of washing filters.

Full Plant Scale Data

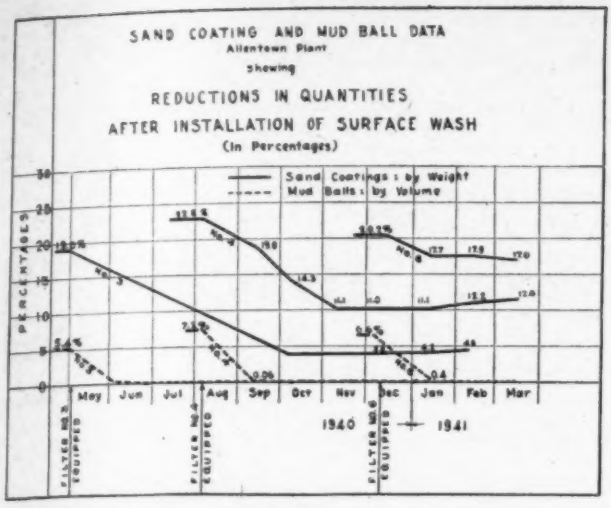
The Allentown filter plant was built in 1928 and takes water from the Little Lehigh River, a stream draining a fertile farming area, with consequently widely varying turbidities. The works comprise an intake well with screens, low lift pumps, a baffled mixing basin, with an actual retention period of about 20 minutes for floc formation, duplicate sedimentation basins of about 2 hours capacity, and 8 rectangular filter units with a capacity of 1.25 m.g.d. each. Alum is used as a coagulant, with pre- and post-chlorination. The only unusual features of the plant are the non-metallic Leopold Duplex Filter Bottoms. The raw water alkalinity is above normal for Pennsylvania and somewhat hard, but is not grossly contaminated. Some few industrial wastes in minor quantities are present in the water.

The history of the Allentown filter units is typical of many other plants, with probably an average amount of mud ball formation, some gravel disturbance, and an occasional hard spot at the outer perimeter of the units and in the corners. Since the plant was built in 1928 the sand has been ejected from the filters twice for the purpose of breaking up mud balls and to examine the condition of the gravel layers.

Conditions at Allentown, the authors feel, average the field quite generally except for the absence of troubles commonly due to metallic bottoms. The plant is operated at full rates with daily shutdowns of several hours each day.

After due consideration of the condition of the filters and other factors involved, and because of the results observed in the experimental filter, a rotating Palmer Filter Bed Agitator was installed in filter No. 3 in April, 1940. The results were so satisfactory, from a visual standpoint, that four additional filters were equipped with Palmer Agitators, the first being installed in July, 1940, and the last two in April, 1941. The remaining three filters in the plant are likewise to be equipped before the end of 1941.

The surface dimensions of the Allentown filters are 20 feet by 22 feet. The Palmer Agitator installed consists of one brass unit with properly placed jets and with an overall length of 19½ feet, the longest arm used anywhere, according to the manufacturer, up to the time of the last installation. In order to provide rigidity for the agitator, sections of galvanized pipe 2½ inches



Graph 1—Sand Coating and Mud Ball Records (Revealing Rapidity with Which Surface Wash Removes Sand Coatings and Clears Out Mud Balls)

in diameter in the form of a cross are fastened to the four walls of the filter with wall flanges—see Fig. 3.

Mud Ball and Coating Reductions

Before the second installation was completed in August, 1940 (filter No. 4), samples of sand were taken from the top 6 inches of the bed and the volume of mud balls accurately measured, using the method advocated by Baylis.[6] In addition, the amount of coating on the sand grains was determined by treating a weighed sample with concentrated hydrochloric acid, washed, dried and reweighed.[7]

These determinations have been repeated monthly since that time. It will be noted in Table 1 and Graph 1 that the average amount of mud balls in the top 6 inches of the seven filters not equipped with agitators was 5.6 per cent. In filters No. 3 and 4, equipped with agitators, after one month of service practically no mud balls remained.

TABLE No. I

Filter	% Mud Balls	Sand Characteristics — Eff. Size	Uniformity Coef.
No. 1	4.3	.63	1.35
No. 2	4.6	.53	1.32
No. 3	0*	.60	1.50
No. 4	7.2	.53	1.40
No. 5	8.3	.55	1.36
No. 6	6.0	.55	1.36
No. 7	2.9	.54	1.40
No. 8	6.1	.69	1.30

*Not tested previous to installation of Palmer agitator. Tests—October 29, 1940.

Unfortunately, no sand coating test was made on the sand in filter No. 3 prior to the installation of the agitator. However, the average coating on the sand in filters No. 4, 5 and 6 before the installation of the agitators was 23.4 per cent. The rate of reduction in sand coating, as the result of surface scouring, is shown in Graph 1, which tells its own story better than can be told in many words.

Wash Water Savings

The authors are unable to confirm claims made by others as to marked savings in wash water through the use of surface wash, either by careful analysis of the Allentown plant data or after more general observations elsewhere. It is conceded, however, that other operators may have collected information demonstrating success in this phase of the operations where filter design may not have been as satisfactory—as at Allentown.

At Allentown it has been the practice to wash each filter unit at a loss of head of 6 feet, or immediately upon the appearance of turbidity in the effluent of such filter, rather than to depend entirely on the loss-of-head rate-of-flow, or time period, as variously and generally practiced. Successful coagulation and sedimentation, as well as the turbidity of the raw water, under Allentown procedure greatly affect the length of filter runs. Data on filter runs at the Allentown plant for the year 1940 are shown in Graph No. 2. The effect of spring and fall rains is reflected in the shorter runs in April and November.

In a study of these filter run figures, consideration should be given to the fact that the sand in the plant has been in use for 12 years, and that considerable variation exists in the sizes and uniformity coefficients in the various units because of the gradual and non-uniform loss of the finer particles.. The possible effects of these sand characteristics has not as yet been studied in detail.

An examination of the graph on filter runs reveal no definite trend in filter run time, nor does it indicate any reasons for a failure to secure longer runs. The general average of the agitator-equipped filters is approximately that of the other units. The high percentage of wash water used for filters No. 3 and No. 4 in the first months after installation of the agitators in these units, undoubtedly was due to frequent washing for demonstration and experiments, rather than to normal procedure.

From the standpoint of increased length of filter runs, therefore, no savings in wash water have been secured at Allentown. The same general impression seems to have been arrived at in other plants under observation, without any definite figures available for confirmation. A lower sand expansion index has been used at Allentown in the agitator-equipped units than in those not so equipped, but the saving in wash water which apparently should be effected has not been confirmed by actual measurement and plant data.

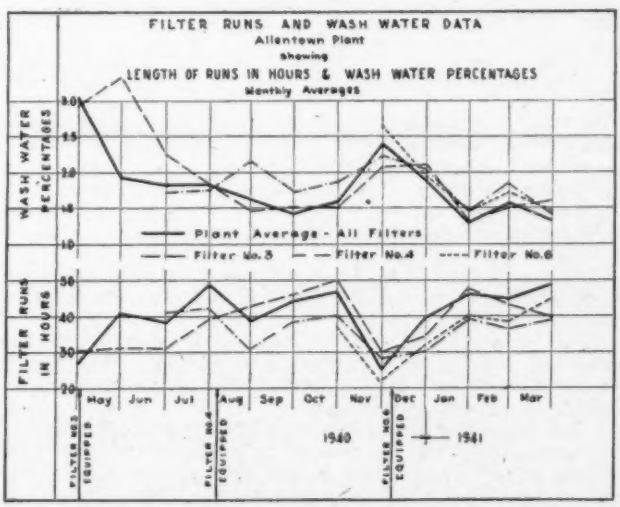
At Allentown, as previously stated, prechlorination is a regular practice. One of the gains effected through the surface wash installations and a further indication of the increased cleanliness of the media in the units so equipped has been the greater residual chlorine maintained in the effluents of these filters, as compared with the effluents of the remaining filters. Data are shown in Graph 3.

Chlorine Economy

It will be noted that the chlorine residuals in the effluents are uniformly and consistently greater for agitator equipped units No. 3, 4 and 6 than for the other units not so equipped. On many occasions the residual of these units has shown very little reduction from that of the residual of the applied water. In actual practice this means eventually a decrease of appreciable amount in the rate of application of pre-chlorine, with subsequent savings in expenditure for this chemical when all filters have been equipped with surface wash facilities.

This effect of the cleaner sand on chlorine residuals (chlorine absorption by the bed) was first noted in December, 1940, some six months after the first agitator was installed in filter No. 3 and three months after No. 4. Detailed studies and observations on the residuals of the separate units was then begun and have since been continued.

The heavy chlorine demand of the average filter unit is well known, and it is sometimes difficult to secure any residual chlorine through a filter bed unless the sand is super-chlorinated before pre-chlorination is begun, or until heavy pre-chlorination has been practiced for some considerable period of time. As a matter of fact, many an operator has been brought to grief through the application of pre-chlorine to dirty filters because of subsequent severe taste and odor production resulting from reactions between

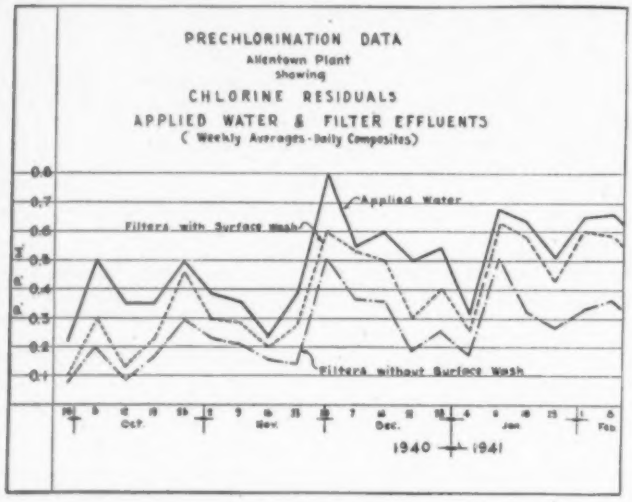


Graph 2—Filter Run and Wash Records (These Records Fail to Show Wash Water Reduction Accruing from Surface Wash at the Allentown Plant)

the chlorine and accumulations within the ineffectively washed sand bed.

At Allentown all filters were thoroughly chlorinated before pre-chlorination was begun. Prior to the time the first agitator was installed, application of chlorine in doses up to 1.14 lbs. per million gallons had been used continuously for approximately 12 months, with the point of application at the influent of the mixing chamber, approximately three hours before the chlorinated water reached the filters.

The decreased chlorine demand of the filtering media after the agitators were installed became apparent almost immediately in filter No. 6, and after about two months of operation, the residual of this unit reached approximately the same figures as for those



Graph 3—Records of Chlorine Removal by the Filters (Indicating the Extent to Which Chlorine Is Absorbed by Coated Sand vs. Clean Sand in Those Filters Equipped with Palmer Agitators—in Itself an Index of Sand Cleanliness as Well as an Operating Economy Realized)

of filters No. 3 and 4, which had been surface washed for about 6 months and 4 months, respectively, prior thereto.

The authors hope to make a detailed study of this problem—the chlorine demand of filter media—in the near future.

Costs of Installation

The effective apparatus of the agitators, consisting of a toggle joint, pipe manifold, and special nozzle openings, all of brass, was purchased at a cost of $197.64 for each unit at Allentown. Auxiliary valves and pipings were purchased by the city and installed by the salaried employes of the city. Basing the labor costs, however, on current hourly rates for skilled mechanics, and adding in the costs of piping, valves, etc., the total cost of installation for one unit (1.25 m.g.d.) was $310. This would mean a total cost of about $2,500 to equip all eight filters in the plant.

In this cost analysis, consideration must be given to the fact that the Allentown filter boxes are almost square in plan (20 by 22 feet), so that it was possible to use only one revolving mechanism to each unit. With filters of dissimilar area, the costs may be greater because of the necessity for installing two or more arms in each bed to cover the entire area. Apparently a reasonable average cost figure, for general use, might be given as $350 per M.G.D. of filter capacity.

Summary

1. To a greater or lesser degree, mud-balls and hard spots are common to rapid sand filter units.

2. Despite careful design, careful operation, and a multitude of practices, no generally successful method of preventing these disturbances had been found prior to the development of the surface wash by Baylis about 1930.

3. In all plants where surface wash has been made an auxiliary to normal bottom wash, improvements in the appearance and cleanliness of filter media have been made.

4. Surface wash piping or the revolving Palmer agitator can be installed without any major interference with normal filter operation.

5. Costs of installation of the Palmer Agitator depends on the size and shape of the filter boxes, but generally speaking, should average about $350 per M.G.D. capacity, including all costs for labor and appurtenances.

6. At Allentown, Pa., with a Palmer Agitator to provide surface wash:

a. Mud balls were practically eliminated in five weeks' operation of a full scale unit.

b. Coating on sand grains was materially reduced.

c. No appreciable saving in wash water has resulted through the use of surface agitation.

d. With pre-chlorination, the effluent of agitator equipped filter units show continuously higher chlorine residuals than do the units washed at high rates but without surface agitation.

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PAINTING DAMP WATER PIPES

In reply to a question regarding the painting of plant piping which is wet from condensed moisture and cannot be taken out of service long enough to dry, The New Jersey Zinc Company prints the following in its periodical, "Paint Progress." The engineer, by the way, stated that wiping the pipes with dry rags before painting had not been satisfactory.

Says New Jersey Zinc:

"We have seen good results obtained by using a turpentine wash to replace the moisture on the pipes and have, as a result, adopted the following method in our own plants:

"The surface is prepared for painting by removing the loose paint and scale by wire brushing and scraping. The dirt and excess moisture are then wiped off the surface and a liberal coating of turpentine is applied.

"The turpentine has a two-fold effect: first to replace the water remaining on the surface by virtue of its preferential wetting property, and second, to 'lift' any loose rust scale remaining on the surface after the mechanical cleaning. A primer coat of standard Zinc Dust-Zinc Oxide paint is then applied directly on the turpentine wet surface, thus providing the necessary rust inhibitive coating. In actual practice, a considerable interval may be allowed between the application of the turpentine and the primer, since the turpentine prevents further condensation of water on the steel.

"Brush application of the primer is preferred to spray application, since it insures the intimate contact of the Zinc Dust with the surface. An 80:20 Zinc Dust-Zinc Oxide formula with a linseed oil vehicle has been used, but a synthetic vehicle, such as phenolic, may be preferable, first, because of the more rapid drying of the synthetic resin formulation, and second, because of the improved water resistance of the film.

"The usual drying interval is allowed, after which the finish coat paint is applied. Just before the application of the second coat, the moist surface is again wiped with turpentine, but care must be taken to avoid an excess of the turpentine, since it might soften the surface of the primer.

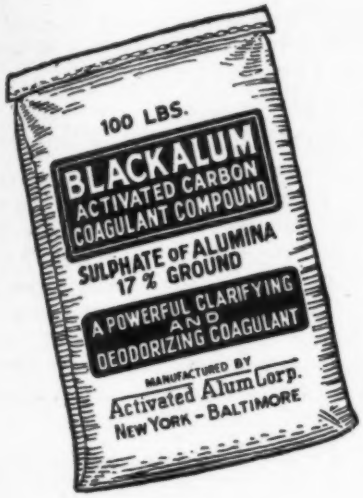
"Either an 80:20 Zinc Dust-Zinc Oxide paint or other suitable metal paint may be used as the finish coat. Colored Zinc Dust paints are available for finishing coats where a distinctive color scheme is desired.

"It has been found that kerosene may be substituted for turpentine to replace moisture on the pipes, but its action is much slower and its assimilation into the paint less positive."

STUART-BRUMLEY CORP.

516 NORTH CHARLES BALTIMORE 1, MARYLAND

DUSTLESS BLACKALUM
ACTIVATED CARBON COAGULANT COMPOUND



BLACKALUM is a powerful deodorizing and decolorizing coagulant. It contains powdered activated carbon. Sulphate of alumina content 17% ground. It provides maximum economy with greatest efficiency.

Activated Blackalum prevents fermentation of sludge in basins. Fast floccing over a wide pH range. It is particularly effective for summer coagulation. It removes tastes from water supplies.

By the use of Blackalum, trouble resulting from red water are successfully eliminated.

Due to its powerful deodorizing and decolorizing properties, water works engineers claim that Blackalum is exceptionally economical.

TEN TECHNICAL ADVANTAGES

1. **A more definitely defined floc.**
2. **Faster settling floc.**
3. **Stabilization of sludge.**
4. **Stabilization of filter sand.**
5. **Longer filter runs.**
6. **Reduced 20% bacterial count in filtered water.**
7. **Less free residual alum in finished water.**
8. **Chlorine demand reduction.**
9. **Dechlorination.**
10. **Taste and odor improvement.**

"Report satisfactory results with a very large reduction in dosage. 100 pounds of Blackalum (new 'stepped-up' Blackalum) gave equal coagulating results with a demand for 171 pounds of another alum—a technical triumph for this new Blackalum."

"We are using dustless Blackalum exclusively. Since we have more storage space we have not had to order alum more than two or three times a year. We used less alum the past winter than any winter since the writer has been in charge of the water works."

USE BLACKALUM — PRODUCE BETTER WATER

—SEND US A TRIAL ORDER TODAY—

It's not the best-looking plant that delivers the best water — *it's the plant that uses* BLACKALUM.

THE ANTHRACITE EQUIPMENT CORP.

101 Park Avenue
NEW YORK CITY, N. Y.

H. G. Turner—Research Engineer—State College, Pa.

ANTHRAFILT — an Improved Filter Medium

Anthafilt and Its Application

Anthrafilt is made from a **selected** Pensylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthracite and sand and saves on freight and handling charges.

Filtration Characteristics

Anthracite granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.

Upward impulse of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effective size of .60 m.m. to .80 m.m. the uniformity coefficient is less than 1.75 in all cases. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32" x 3/16"
No. 3. Anthrafilt—3/16" x 5/16"
No. 4. Anthrafilt—5/16" x 9/16"
No. 5. Anthrafilt—9/16" x 13/16"
No. 6. Anthrafilt—13/16" x 1-5/8"
No. 7. Anthrafilt—1-5/8" x 2-7/16"
The above sizes have 20% tolerance.

ANTHRAFILT ECONOMY

When Used in Existing Filtration Plants

Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging, mounding and air binding.

When Used in New Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs

CLEANING FILTERS WITH SULPHUR DIOXIDE

By J. G. PATRICK
Chemist, West Virginia Pulp & Paper Co., Luke, Md.

SAND grains of rapid sand filters frequently become coated with mud, biological slime, manganese, organic matter, iron, floc particles, or a combination of two or more of these film-building materials. When sand grains become thus coated the filter suffers loss of efficiency; mud balls and hard-spots appear, wash water requirements go up. The "schmutchdecke" era is of the past, and it has become well established that the "clean filter is the best filter." Several methods have been employed to loosen the coatings from filter-sand grains sufficiently to allow prevailing washing rates to remove them.

Caustic soda and chlorine, so effective in many cases, has been found of little value in loosening coatings made up in good part of manganese and iron oxides. Then the idea of utilizing an effective reducing material was considered. In looking for the reducing agent most simple to apply and least costly, the possibilities of sulphur doxide gas came to mind. The scheme proved simple and effective.

This paper tells of some of the experiences with the sulphurous acid method of sand cleansing in four filter plants. So successful has been the scheme that the writer has, for protective reasons, taken out U. S. Patent 2,069,621, covering "A Method of Cleaning Sand Filter and Appurtenances." This patent has been assigned to West Virginia Pulp & Paper Co. and its industrial chemical sales division.

Part I—Early Experiences at Luke, Md.

The process was developed at the 12 m.g.d. filtration plant of the West Virginia Pulp & Paper Co. operated under the writer's supervision.

The raw water is heavily contaminated with acid coal mine wastes contributing the useful but, at the same time, troublesome iron and manganese. Caustic soda, and alum to supplement the iron and aluminum salts in the raw water, are employed as the coagulating chemicals. Activated carbon is added to the raw water to assist in clarification. The iron content of the raw water averages 1.00 p.p.m. and is reduced to 0.17 p.p.m. by treatment. The manganese is less affected, being decreased only from 0.30 to 0.26 p.p.m. because of partial oxidation.

Early Cleaning Methods

After two years of service, attempts were made to clean the sand beds by treatment with a 2 per cent solution of caustic soda followed by stirring the sand by an air-lance. The sand was only partially cleaned. Total cost, including all incidentals, was $37.50 per filter of 154 cubic yards. Other efforts were made to clean the under-drains and filter bed by chlorine applications to the wash water, but this was only partially successful. Mechanical treatment was applied to break up the mudballs.

Sulphur Dioxide Tried

Sulphur dioxide had already proved successful in removing manganese deposits from the water mains in the mill. These mains were found to be heavily coated with the undesired hydrated manganese dioxide, which broke away to produce dark and smudgy specks that spoiled many tons of high grade white paper. A 0.2 per cent solution of SO_2 water (sulphurous acid), allowed to stand in the mains 6 hours, reduced and removed the manganese effectively.

Laboratory tests were first made by treating the filter sand with SO_2 water of various strengths. These tests showed a concentration of 3.0 per cent SO_2 in the water cleaned the sand to its original white, sharp grained condition.

Filter Bed Treated

The SO_2 treatment was then tried on a large scale with a filter bed. Preliminary to introducing the SO_2 the filter was prepared as follows:

(1) Filter thoroughly washed, to reduce gas consumption by loose material.

(2) Water drawn down through sand into gravel.

(3) Main effluent header and wash water valve closed.

(4) All small pipe connections across the Venturi and other meters closed.

(5) A cylinder of liquid SO_2 (similar to chlorine cylinders) was then attached to the effluent header by a brass pipe and standard chlorine tank connections and the SO_2 added as a gas. A heat evaporator was necessary to hasten the exit of the gas, and even that required a few hours to empty a tank. (In later applications the cylinder was inverted and 150 pounds of liquid SO_2 could be drawn off in 10 minutes, if desired.)

(6) As the liquid SO_2 was applied, the wash water valve was opened a little, water permitted to enter and force the sulphurous acid into the under-drains and up through the gravel and sand to a one-foot depth above it.

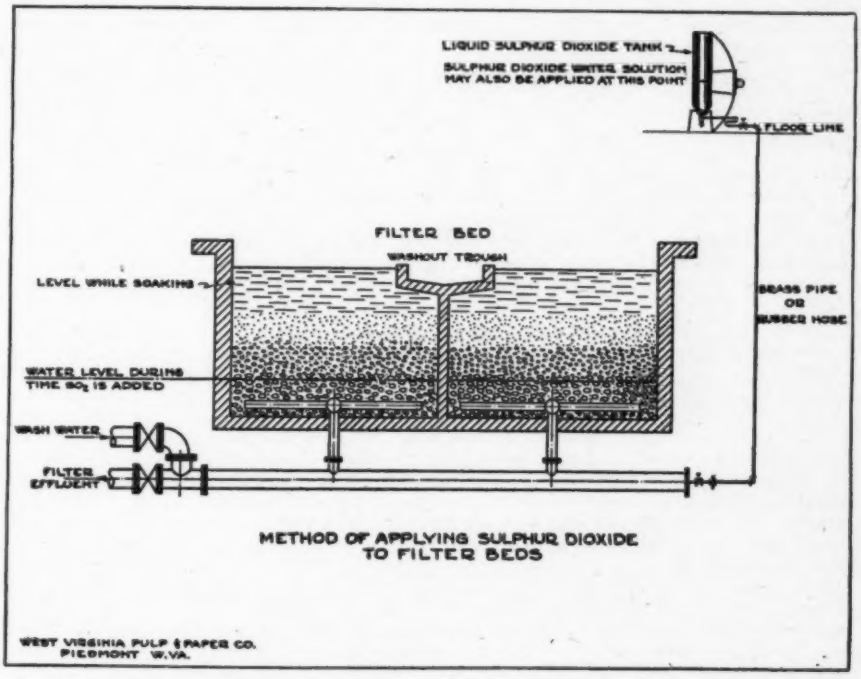
(7) After standing the required time the filter was given at least three back-washings.

Following the gas treatment the first washings were dark gray, changing to a light yellow. An analysis of the early material proved it was chiefly iron-aluminum floc discolored with some manganese dioxide and activated carbon. The yellowish substance was iron and manganese in solution.

The filters were so improved in efficiency and capacity, other treatments were given as conditions warranted.

Pertinent data giving the strength of solution, cost, and results obtained in treating three different 3 mil. gal. filter units (154 cubic yards of sand each) are given in Table I.

Since most of the coating was removed from sand, gravel and pipes the concentration of the solution for future treatment may be diminished and the interval between treatments extended to maintain practically clean surfaces.


LIQUID SULPHUR DIOXIDE TANK
SULPHUR DIOXIDE WATER SOLUTION MAY ALSO BE APPLIED AT THIS POINT
FLOOR LINE
FILTER BED
WASHOUT TROUGH
LEVEL WHILE SOAKING
BRASS PIPE OR RUBBER HOSE
WATER LEVEL DURING TIME SO_2 IS ADDED
WASH WATER
FILTER EFFLUENT
METHOD OF APPLYING SULPHUR DIOXIDE TO FILTER BEDS
WEST VIRGINIA PULP & PAPER CO. PIEDMONT W.VA.

Sketch Depicting Method of Applying Sulphur Dioxide to Cleanse Filter Beds

The quantity of SO_2 used was less than the amount shown by the laboratory tests; only enough to make a weak acid solution which is quickly spent, and likewise harmless to metal surfaces.

A dosage concentration of 0.3 per cent SO_2 appears to be rather effective without being corrosive at Luke. At this concentration, 150 pounds of SO_2 makes 6,000 gallons of sulphurous acid to fill the voids in the gravel and sand bed.

Mechanical agitation or raking the bed during treatment hastens the action. Naturally the longer the soaking period, within limits, the cleaner the sand becomes.

Results of Treatment

1. On the hard and over-capacity draughts there was no floc or dirt drawn through the filter bed.

2. Mud balls disintegrated.
3. The wash-water was more uniformly distributed throughout the sand bed.
4. Sand was lighter in color, having lost much of its coating; its buoyancy, too, had decreased.
5. Filter runs were extended 25 per cent in time between washings.

Advantages of the Method

1. Liquid SO_2 is easily obtained in convenient portable cylinders at a reasonable cost. Usually the commercial grade can be purchased at 10 to 12 cents per pound.
2. The application is simple with most filters. The cylinder may be connected to brass pipe by means of the standard flexible tubing and the adapters used with chlorine cylinders. (Rubber tubing, with brass union connections, may be used in place of pipes.) The average cylinder can be emptied as liquid within 10 minutes. (See sketch.)
3. Labor cost is small, requiring only a few man-hours to wash the filter preparatory to, and after treatment, and connect piping—a one-man job.
4. The SO_2 reacts not only with the manganese but also with the iron and other matter present. The sulphurous acid kills bacteria and plankton, disintegrates mud balls, and opens closed ports in the collector pipes. It reaches into inaccessible parts of the filter.
5. The SO_2 is less dangerous to handle than many other aggressive chemicals, especially sulphuric acid, sodium hydroxide, etc.
6. The removal of the sand, as with the ejector method, is unnecessary.

Preparations for Using SO_2

These tests demonstrated that sulphur dioxide gas must be respected and handled with reasonable caution.

All pipe connections must be kept tight. The gas is irritatingly unpleasant. A gas mask equipped with an "acid" gas cannister is good protection to have at hand in case of an escape of the gas in a poorly ventilated room.

The liquid striking a moist skin may cause a "frozen-burn" from the resulting quick evaporation.

Comments

It is believed the sulphur dioxide solution (sulphurous acid) cleans the pipe interiors, the gravel, and the sand in the following manner. The coating existing mostly of iron hydroxide, hydrated manganese dioxide, silica, calcium and magnesium, alumina and organic matter, is acted upon by the sulphurous acid which reduces the manganese to the soluble manganous salts and the ferric iron to ferrous iron at least in part. The oxidation continuing, sulphuric acid is formed to some extent. The acid dissolves or loosens the incrustants, breaks apart agglomerations, scours the gravel, and unplugs collector pipe orifices that may be partially closed.

It is generally more economical to apply small doses of SO_2 at frequent intervals, since so little labor is required, thus removing a small portion of the coating each time, than to use a strong dose at longer intervals to get rid of a greater amount of the coating at one treatment. With the weaker solution, risk of corrosive attack on metal parts is far less.

It is our belief that the sulphur dioxide method of treating filters is the answer to the problem of loosening sand coatings for easy removal. For removing the calcium carbonate coating from filters in water softening plants, the scheme is not recommended, however. This because of the dangers of cementation of grains, caused by conversion of the calcium carbonate to calcium sulphite and, possibly, some sulphate where oxidizing compounds (iron and manganese) are present.

[Calcium carbonate can most effectively be removed by acid or chlorine water to form soluble chlorides.—Ed.]

Part II—A Demonstration at Baltimore, Md.

A demonstration was arranged with Mr. James W. Armstrong, Filtration Engineer, Baltimore, Md., to study the merits of the sulphur-dioxide process.

The raw water at this plant is from the Gunpowder River, where several billion gallons are impounded in Loch Raven reservoir. It contains an average of 0.5 p.p.m. iron (Fe); 0.2 p.p.m. aluminum (Al); and 0.27 p.p.m. manganese (Mn); and 38.0 p.p.m. alkalinity. Frequently the manganese content runs so high as to necessitate the use of lime and iron to precipitate it, with the iron, ahead of the filters.

The Filter

The filter, of 4 m.g.d. capacity, has a sand surface of 1,440 square feet, there being 18 in. sand depth and 18 in. of graduated gravel with a volume of 160 cubic yards. Voids are calculated at 40 per cent = 1,728 cubic feet, or 108,000 lbs. of water to fill the void spaces.

Sand is usually cleaned by an ejector-washer about every two years, requiring four men, at an approximate cost of $50 per filter. The gravel is dug out and run through a revolving grading screen, aided by hard jets of water. Much time is required to replace the gravel in the separate layers of the proper size.

Before the SO_2 treatment the sand had a deep brownish-black color and was sticky enough to be moulded wet. Several fair-sized mud balls and ridges were prominent. The gravel, as checked in an untreated filter bed (No. 14), had a pasty black coating about ⅛ inch thick. There was a thin coating of mud on top of the sand bed, and in some sections this mud had penetrated several inches into the sand. The concrete walls and troughs were coated with a dark slime.

The filter was given a thorough back-washing for 4½ minutes (151,000 gallons) preceding the treatment. The water rose unevenly through the sand, indicating several quiet or inactive collector pipe ports or hard spot interference.

SO_2 Application

The SO_2 supplied by the Virginia Smelting Co. was added as liquid. (See sketch.) Using the general procedure already described, the water level was lowered to near the bottom of the gravel (indicated in a gauge glass on outside of filter); the SO_2 was introduced; water then added slowly through the underdrains until the level was above the top of the sand. The soaking in this solution of sulphurous acid continued overnight. The filter was then backwashed a few times, and samples taken of the waste water from the top at the wash troughs and also underneath, from the rewash line. Examinations of the sand and the gravel were made and the effluent and wash water analyzed for iron and manganese after each treatment.

A connection was made with the cast-iron effluent header by means of a ⅜-inch brass nipple and valve. The SO_2 cylinder, on the operating floor above, was connected thereto with a flexible ⅜-inch rubber hose. An auxiliary valve, with union connection, was on the hose at the cylinder to aid in disconnecting the container and to prevent the escape of any SO_2 gas.

TABLE I

Application No.	SO_2 Lbs.	SO_2 Pct.	Soaking Period, Hours	Wash Water, Gals.	Cost: Labor	Cost: SO_2	Cost: Wash Water	Cost: Total	Cost: Per Cu. Yd.
(1)	100	0.100	5	200,000	$0.80	$10.00	$1.60	$12.40	$0.08
(2)	75	0.075	4	200,000	0.80	7.50	1.60	9.90	0.06
(3)	150	0.150	8	200,000	1.00	12.00	1.60	14.60	0.10

The quivering motion of the flexible hose, and the coating of frost on the brass valve and pipe at the effluent header, were good signs the liquid was flowing. The disappearance of the frost served as a good indicator that the cylinder was empty of liquid SO_2 and could be disconnected.

(Strong ammonium water serves well in detecting any leaks of SO_2, because vapors of ammonium sulfite (smoke) quickly form.)

Practically the total 1,950 pounds (13 by 150 lbs.) of SO_2 was added without any annoyance of escaping gas. The only perceptible odor was momentary during the occasional opening of a test valve for SO_2 water. The 1,950 pounds of liquid SO_2 (based on the 108,000 gallons in the 40 per cent voids in the sand) produced a 1.80 per cent solution. After dosing, water was introduced underneath to force the sulphurous acid formed up through and above the sand bed. Thus it stood during the overnight soaking period.

At the end of this time the filter was backwashed. Samples were collected from the wash troughs and from underneath the bed at the rewash or waste pipe, and other observations were made. The water samples were tested for pH, iron, manganese, and unspent (residual) sulfites.

Special Equipment

A convenient piece of apparatus, which facilitated and expedited the handling and the emptying of the SO_2 tanks, was a portable inversion stand supplied by the Virginia Smelting Com-

pany. This device consisted of a simple semi-circular rack made of one-inch angle iron. It was so balanced for rolling in one direction to pick up the full cylinder after clamping in place. A reverse roll inverted the cylinder to the vertical position, with the tank valve readily accessible for attaching the rubber hose. Two small wheels, midway of the arc, permitted easy wheeling in transportation, when the container was left in a horizontal position. It is truly a one-man, one-hand rack, allowing cylinders to be attached, moved around, or inverted with little effort. A 150-pound cylinder could be set into position and connected in 1½ minutes, emptied in 10 minutes, disconnected and removed in 1½ minutes—the total of 13 minutes being required for the complete cycle.

APPROXIMATE COST

Sulfur dioxide—1,950 lbs. at $.08	$156.00
Wash water—2,435,000 gals. at $8.00 M.G.	19.26
Labor—preparation—examination of bed	15.00
Total	$190.26
Total cost per cu. yd. of bed (160 yds.)	$1.19

After the third wash the sand and the gravel were examined by digging to the collector pipes. The sand was clean, bright in color, and the last two (larger) layers of gravel still showed good-sized areas of partly loosened or semi-dissolved typical black and pasty coating. With a longer soaking period or a higher velocity of wash water it is believed this coating would have been eliminated by the treatment, for it was easily washed off by one or two dips in quiet water. With the gravel in another filter (No. 14) untreated with SO_2, this pasty coating required considerable agitation or rubbing to remove it from the gravel. Further evidence that this coating was effectively loosened, and partially dissolved, was shown by the fact that the filter had to be drained to waste for several hours before it was sufficiently free of manganese content to warrant turning the water into the clear well.

Results from Treatment

Inasmuch as primary interest was in removing the coating on the sand and gravel, and this coating was composed chiefly of iron and manganese, these objectionables have been used as a criterion of cleaning in the following data. Results are expressed in pounds per ton (2,000 lb.) of the sand.

	Pounds per Ton	
	Iron	Manganese
Sand—Before SO_2 Treatment—		
Top of bed	30.83	7.45
Bottom (next to gravel)	22.38	12.44
Sand—After SO_2 Treatment—		
Top of bed	.10	2.49
Bottom (next to gravel)	.08	1.99

Assuming that if the samples of wash water, containing the dissolved materials, were true representative composite samples, and based on the approximate two million gallons of wash water used in clearing the beds, there were removed in the backwash 410 lb. of iron and 1,892 lb. of manganese. With such a large unit, however, it was impossible to get truly representative dirty water samples.

The SO_2 treatment was effective in reducing the size of most mud balls and eliminating or disintegrating some entirely. The sand was cleaner and looser throughout, as shown by the surface motion during backwashing.

The dark color of the backwash water after the soaking, the floc it contained, the brightening of the sand, and the softening and the removal of the greater portion of the black and pasty coating on the gravel and the underdrains, are all evidence that the entire filter was materially cleaned. A few clay-like mud balls remained intact.

Part III—Cleaning the Batavia N. Y. Filters

At the municipal water filtration plant of Batavia, N. Y., an SO_2 cleaning demonstration was successfully made November 13-15, 1937.

Two filter beds were treated, one with a 2 per cent solution of sulphur dioxide (sulphurous acid) based on the weight of water in the filters; and another, partly cleaned with a one-half dose, or 1 per cent SO_2. Preliminary laboratory tests on small samples had determined that a 2 per cent SO_2 application would restore the sand to its original quartz whiteness. The contrast between the uncleaned and the cleaned sand was striking. The partly cleaned sand gave an intermediate gray-white color.

After demonstrating to Mr. H. M. Cook, Supt. of Water Works and Filtration, how easily the SO_2 could be applied, he treated the rest of the filter units himself with 1 per cent applications.

Condition of Filter Beds

The sand in these beds was not as dirty as some, although it bore a dark brown coating of sufficient thickness to cause the adhesion of sand grains to each other. There has been no trouble with the coating breaking off and clouding the effluent. The beds were last cleaned in 1930 when Leopold type filter-bottoms were installed. Mud balls were absent due probably to the hard hosing treatment which has been a practice after each backwash for some weeks. The condition of the gravel and the underdrain is not known as it has been some time since they were inspected.

SO_2 Dosage—Recirculation Tried

The usual procedure was employed in treating the Batavia filters. They were given a good backwash, drained through the effluent waste, then wash water introduced to bring the water level up into the gravel bed. The depth of this water was determined by a small pipe gage fastened to the effluent header. The liquid SO_2 was added from an inverted cylinder through the rubber hose and brass connections into a tap made between the valves and the filter manifold or underdrain header. After the addition of the SO_2 enough wash water was run in to bring the solution level to a few inches above the top of the sand bed. The SO_2 hose was then disconnected and a one-inch hose was attached to the top and connected to the suction side of a small centrifugal pump delivering 8 gallons per minute. The discharge from this pump was carried away by ordinary garden hose, the nozzle end of which was kept submerged under the water above the sand. Every 30 minutes this nozzle was moved to a new point on the sand bed to insure a positive action at all sections. This circulation accelerates the activity of the sulphurous acid and it was a marked improvement over the natural diffusion experienced at Luke, Md., and Baltimore. It is the first time that recirculation was tried and it is believed it would be especially advantageous not only to insure movement of the solution and sulphur dioxide economy, but also in breaking up mud balls and enlivening dead spots.

This recirculation continued for 24 hours, at the end of which time the sand under the 2 per cent solution had entirely lost its coating and had regained its original color. As mentioned above, the test with the 1 per cent solution did not remove all incrustants.

Within a few hours the supernatant liquid on top of the sand changed to a deep lemon color and some SO_2 odor came from this, but at the end of the soaking period there was no trace of SO_2. The filter was backwashed several times as follows:

Back Washing	Time	Gals.	Waste Water	pH
1st	9 min. (Stood 1 hr.)	30,000	Amber	6.0
2nd	7½ (Stood 1 hr.)	25,000	Light floc.	6.2
3d	7	23,000	Clear	6.3

The first backwash water was a deep amber color covered with several inches of foam. After the above three washings, the filter was put in operation with the effluent run to waste for about 5 hours, and when the pH reached 7.1 was put "on to the line." Measurement of the sand bed before and after treatment showed but little change in depth. That the sand was uniformly cleaned throughout the bed was shown by digging to a depth of two feet in several places. Twenty-four agar plates and fermentation tests on the filter effluent, after cleaning, gave negative results. This is more proof that the sulphurous acid has bactericidal and bleaching action as well as chemical action.

Part IV—Cleaning the Filter Beds of the Long Island Water Corporation, Valley Stream, L. I.

A fourth demonstration was made at the request of the Freeport Sulphur Company which has been studying new applications of sulphur compounds through a fellowship at New York University, New York City, under the supervision of Prof. L. V. Carpenter.

The sand was incrusted with a bright reddish iron oxide. These filter beds were a striking example of an unusual condition, since the water is heavily loaded with iron and manganese and the chief problem has been to remove these compounds.

One of the four 1.5 mgd. filters was treated with a 2 per cent solution of sulphur dioxide. This filter bed had recently been opened to examine and replace strainer head, and samples of the gravel and sand were obtained. The gravel bore a typical blackish-brown pasty coating about 1/16 in. thick of the hydrated manganese dioxide. As the sand was uniformly incrusted with ferric oxide, more on the order of a stain, this red oxide when dry in the sunlight caused the sand grains to resemble garnets. This coating furthermore is an advantage as it has a contact or catalytic action in iron removal. It is claimed that this iron incrustant once eliminated would reduce the efficacy of the sand as an iron remover, and it was estimated that several weeks

would be required to form a new coating. Apparently the coating has become constant since the effective size of the grains has increased only 0.08 mm. with 4½ years' continuous service.

Since the gravel was so heavily coated it is reasonable to think the interior of the effluent header and other lines carry similar coating.

Although the sand in some beds has been shifted by an ejector this is claimed to give little cleaning action. The sand was free and there was evidence of mud balls or effect on filter runs, etc. The filters are washed every 24 hours. It is reported that the interior of the distribution mains to the consumer are being steadily coated with a black deposit which occasionally breaks away and becomes apparent in the water. This further suggests that the manganese is being deposited within the mains. The raw water is from deep wells from 150 to 200 feet deep. A typical analysis of raw and filtered water is as follows:

	ppm.	
	Raw	Filtered
Iron	2.0	0.10
Manganese	0.03	0.00
Hardness ($CaCO_3$)	21.0	25.00
Carbon dioxide	19.0	2.00
Alkalinity, M. O.	14.0	24.00
Color	5.0	0
Turbidity	5.0	0
Dissolved oxygen	...	6 g/1
pH	6.0	7.2

Treatment consists of aeration by an Aeromix unit, followed by the addition of 0.6 grains per gallon of lime for oxidation and precipitation of most of the iron during the 15-minute sedimentation preceding filtration. The effluent of the rapid sand filters is stored in open, slow sand filters through which the water is drawn from the bottom and pumped to the distribution mains, hence having double filtration.

SO_2 Treatment

For cleaning filter No. 3 the quantity of liquid SO_2 required for a 2 per cent solution was calculated as follows:

16 ft. x 22 ft. x 5 ft. bed	=	352 sq. ft. area = 1,760 cu. ft.
1,760 cu. ft. x 62.5 x 40% voids	=	44,000 lb. H_2O
To produce 2% solution	=	880 lb. SO_2
Pipes 1x10 in. + 1x12 in. x 16+16+11 = 32 cu. ft.	=	40 lb. SO_2
3 in. water above sand = 0.25 ft. x 352 = 88 cu. ft	=	110 lb. SO_2
Total		1,030 lb. SO_2

Actually used 1050 lb. SO_2 @ 9 cents pound = $94.50.
Total solution 6,180 gals.

The regular procedure was used, washing the filter thoroughly, draining it, then adding enough water to take up the SO_2 which was applied in stages, as noted below, to obviate high concentration of sulphurous acid in the header for any long period. The seven cylinders of liquid SO_2, 1,050 lb., were added without any leaks or other annoyances.

Recirculation, as described in the Batavia work, was employed during the 15 hours' soaking period, with a 9-gallons-per-minute pump which actually turned over the solution (theoretically) 1.3 times. The hose nozzle was kept submerged and moved at regular intervals over the surface at all times. A slight odor of SO_2 arose from the surface of the bed for the first hour and then disappeared. Within five minutes after the water had been raised to above the sand the solution had begun to turn red and at the end of the soaking period the color was a deep crimson or blood red, too dark to see through.

Back Washing

At 11 a.m., the next day the filter was backwashed as follows:

Wash	Time	Color of Solution	Wash Water, Gals.
1	10 min.	Blood red	50,000
		Stood 15 minutes	
2	5 min.	Lemon yellow	25,000
	Apparently no change in deep red color of sand at 12" below surface. Stood 3 hrs. 10 min. pH 4.2.		
3	5 min.	Light lemon yellow	25,000

At 3:45 p.m. filter put in operation, effluent run to waste. pH 5.7.

At 9:00 p.m. filter put into service. Effluent pH 7.0.

A sample of the gravel was removed several days after the treatment and was found to be clean or free of the black manganese and iron coating.

The sand, however, remained little changed in appearance. Since this iron incrustant is an advantage in the water treatment it is well it retained its iron oxide coating.

Results

Sand Examination

Professor Carpenter and his associate, Mr. John Coates, found the following:

Sieve Analysis	Effective Size	Uniformity Coefficient
New sand	0.44	1.59
Before SO_2 treatment	0.52	1.56
After SO_2 treatment	0.485	1.59

The effective size changed by the treatment from 0.52 to 0.485 while the uniformity coefficient remained practically constant.

Further analysis showed the sand incrustants (Fe_2O_3) before cleaning were 6.9 per cent and 5.9 per cent after treatment. Calcium and magnesium were not found in the incrustants, but a small amount of manganese was present.

Analysis of water above sand after recirculation 15 hours* (Piedmont Laboratory):

	Gms./L.	ppm.	Lbs. in Filter Solution
Total solids	30.1	30,100	1,550
Volatile and organic matter	11.0	11,000	564
Silica (acid insol.)	0.9	900	47
Iron	5.9	5,900	310
Manganese	2.4	2,400	124
Calcium	2.1	2,100	108
Magnesium	1.4	1,400	72

(Ed. Note: Since original publication of this article the use of sulphur dioxide to clean filters has found favor in a number of other plants throughout the country, notably Louisville, Ky., Noonan, Ga., Tarrytown, N. Y., Passaic Valley, N. J., and Perth Amboy, N. J. among others.)

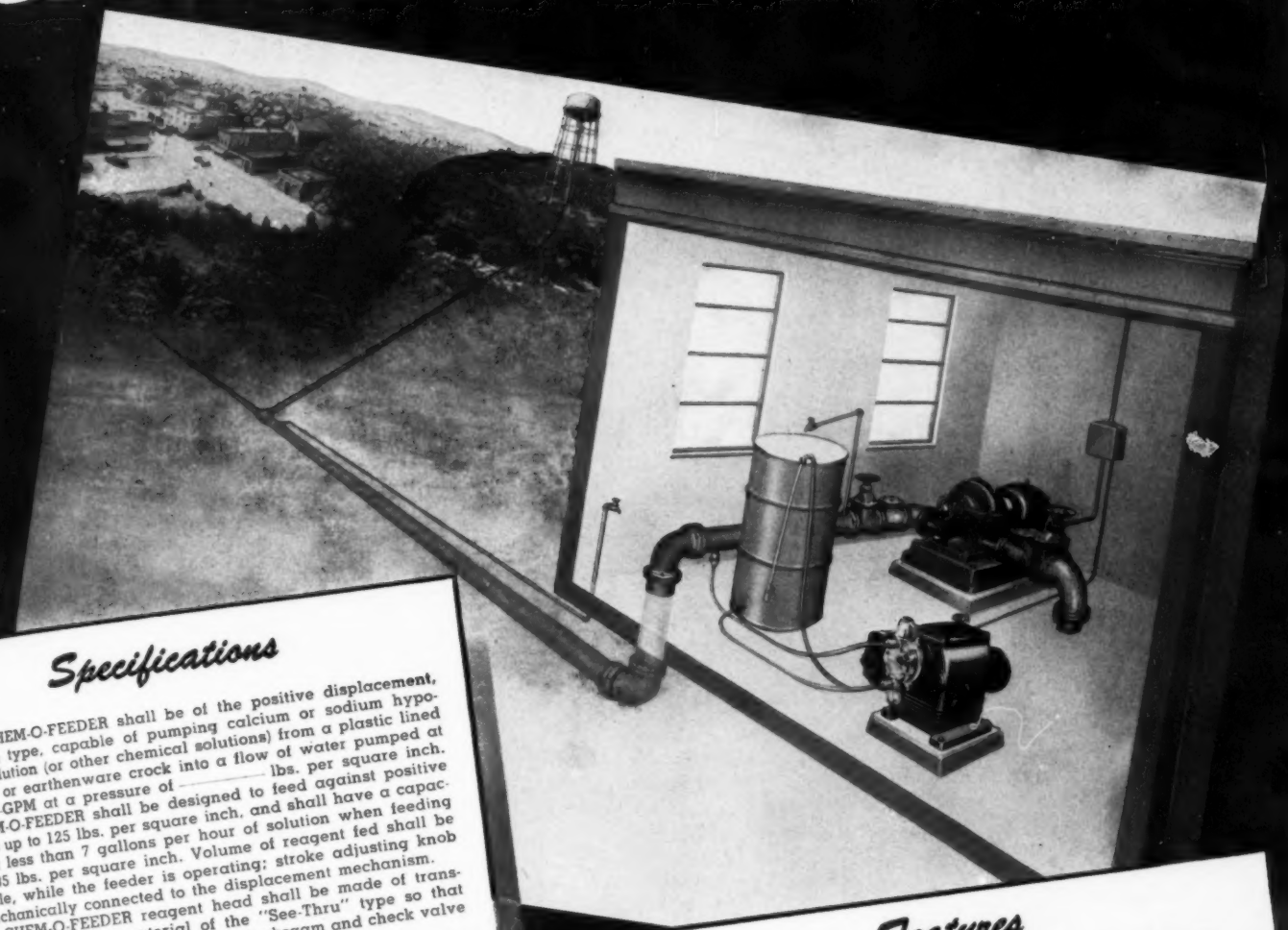
*Based on 6,180 gallons in filter, and assuming this was a representative sample.

PROPORTIONING CONCRETE

Proportions of Mixtures			Material For One Cubic Yard Concrete — Gravel ¾" and under			Stone 1" and under, dust screened out			Stone 2½" and under, dust screened out		
Cement	Sand	Stone	Cement Bbls.	Sand Yards	Stone Yards	Cement Bbls.	Sand Yards	Stone Yards	Cement Bbls.	Sand Yards	Stone Yards
1	2	3	1.54	.47	.73	1.70	.52	.77	1.73	.53	.79
1	2	4	1.34	.41	.81	1.46	.44	.89	1.48	.45	.90
1	2	5	1.17	.36	.89	1.27	.39	.97	1.29	.39	.98
1	2½	4	1.24	.47	.75	1.35	.52	.82	1.38	.53	.84
1	2½	5	1.10	.42	.83	1.19	.46	.91	1.21	.46	.92
1	2½	6	.98	.37	.89	1.07	.41	.97	1.07	.41	.98
1	3	5	1.03	.47	.78	1.11	.51	.85	1.14	.52	.87
1	3	6	.92	.42	.84	1.01	.46	.92	1.02	.47	.93
1	3	7	.84	.38	.89	.91	.42	.97	.92	.42	.98
1	4	6	.83	.51	.77	.90	.55	.82	.92	.56	.84
1	4	7	.77	.47	.81	.83	.51	.89	.84	.51	.90
1	4	8	.71	.43	.86	.77	.47	.93	.78	.48	.95
1	4	9	.65	.40	.89	.71	.43	.97	.73	.46	1.01

1 Bag of Cement ..... = 94 Lbs.
1 Bag of Cement ..... = 1 Cu. Ft.
4 Bags of Cement ..... = 1 Bbl.
1 Bbl. of Cement ..... = 400 lb. Gross, 376 lb. Net

Heavy Duty
CHEM-O-FEEDER



Specifications

The CHEM-O-FEEDER shall be of the positive displacement, diaphragm type, capable of pumping calcium or sodium hypochlorite solution (or other chemical solutions) from a plastic lined steel tank or earthenware crock into a flow of water pumped at _____GPM at a pressure of _____ lbs. per square inch. The CHEM-O-FEEDER shall be designed to feed against positive pressures up to 125 lbs. per square inch, and shall have a capacity of not less than 7 gallons per hour of solution when feeding against 85 lbs. per square inch. Volume of reagent fed shall be adjustable, while the feeder is operating; stroke adjusting knob to be mechanically connected to the displacement mechanism.

The CHEM-O-FEEDER reagent head shall be made of transparent, molded plastic material of the "See-Thru" type so that the operator can see the action of the diaphragm and check valve lifts, as well as the amount of liquid being fed.

The electric drive motor shall be a stock type motor, obtainable in any city, (same type motor used in oil burners, refrigerators, etc.) and shall be at least 1/6 horse power. No special or midget fractional horse power motors shall be acceptable because of replacement difficulty.

Design shall be such that water line need only be drilled at one point to permit chemical injection, and no additional drillings need be made for operating or balancing water.

The chemical measuring and displacing means shall not require a packing gland as these are subject to leakage, nor shall a secondary transfer fluid piston be required which may need packing glands and periodic replenishing of fluid.

The CHEM-O-FEEDER shall be furnished complete with all accessories necessary for the installation, such as hose or tubing, automatic injection nozzle check valve, combination strainer and foot valve and also spare and replacement parts for one year's service.

The apparatus shall be warranted by the manufacturer against all defects in material and workmanship in all its parts for a period of one year from date of delivery.

Features

"SEE-THRU" REAGENT HEAD
LONG-LIVED DIAPHRAGM
FEEDING RATE
INSTANTLY ADJUSTABLE
CONTINUOUS FEEDING
DESIGNED FOR LONG SERVICE
AMPLE POWER
MANY APPLICATIONS

Bulletin SAN-4

Bring Your Proportioning Problems to -

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" Chemical Feeder Headquarters

Design The design of % Proportioneers % equipment is the result of long specialization in the development and perfecting of proportioning equipment for countless uses in many fields — Municipal and Industrial. This "know how" is invaluable in assuring the best solution to your proportioning problems. Write us for recommendations.

Construction With complete manufacturing facilities "under one roof" % Proportioneers, Inc. % control every step in the production of their equipment—from casting to final inspection. Such close supervision through every phase of machining and assembling, assures uniform high quality in every % Proportioneers % unit.

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PART 7

SEWAGE TREATMENT

WATER WORKS
& SEWERAGE

REFERENCE & DATA SECTION

1944

% PROPORTIONEERS, Inc. %

"CHEMICAL-FEEDER HEADQUARTERS"

9 NO. CODDING STREET, PROVIDENCE 1, R. I.

Representatives in Principal Cities

Raw Sewage Conditioning Using Ferric Chloride and Lime can be controlled in proportion to variable flows thru the Venturi Tube, or over a Weir, measuring the influent. Ferr-O-Feeder (Fig. 1) can handle concentrated 43% ferric chloride or any dilutions; also ferrous salts and practically any other chemicals needed in sewage plants.

Fig. 1—Standard Ferr-O-Feeder

Sludge Dewatering — Sludge dewatering plants using vacuum filters, must automatically control coagulant administered. A Ferr-O-Feeder, used as an adjunct to the vacuum filter, measures ferric chloride and delivers it under pressure to proper point of application in sludge mixing chamber. Ferr-O-Feeder not only accurately measures corrosive liquids but, due to positive displacement method, can deliver the chemical remotely to upper floors of the plant—wherever the filters and dewatering equipment may be located. This eliminates the need of additional rubber lined pumps for lifting or moving ferric chloride from storage to point of use. Ferr-O-Feeder is controlled by cross connection to sewage pumps; to drive motors of vacuum filters; or by belt chain and sprocket connection to bucket elevators (see Fig. 2).

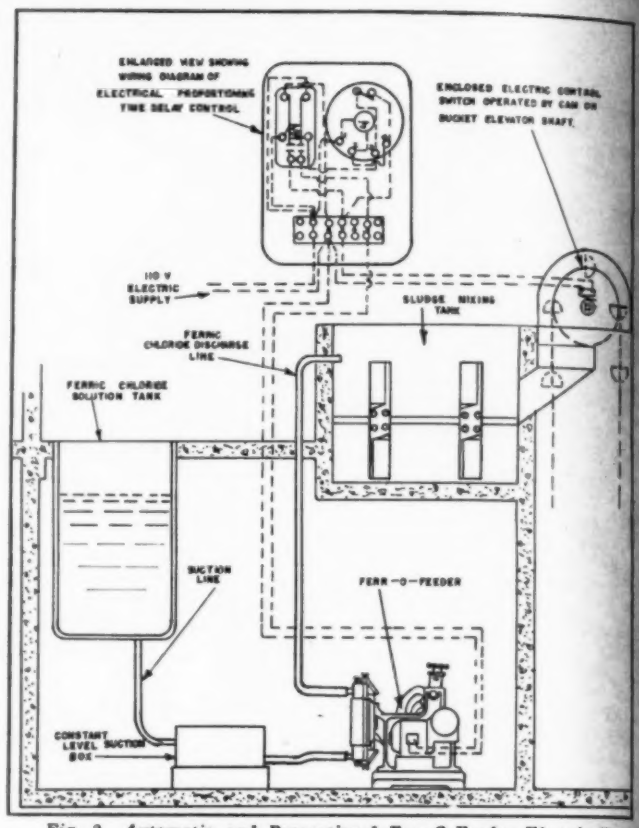
ENLARGED VIEW SHOWING WIRING DIAGRAM OF ELECTRICAL PROPORTIONING TIME DELAY CONTROL
ENCLOSED ELECTRIC CONTROL SWITCH OPERATED BY CAM ON BUCKET ELEVATOR SHAFT
110 V ELECTRIC SUPPLY
SLUDGE MIXING TANK
FERRIC CHLORIDE DISCHARGE LINE
FERRIC CHLORIDE SOLUTION TANK
SUCTION LINE
FERR-O-FEEDER
CONSTANT LEVEL SUCTION BOX

Fig. 2. Automatic and Proportional Ferr-O-Feeder Electrically Controlled and Paced by Sludge Elevator Shaft Revolutions.

Heavy Duty Midget Chlor-O-Feeder Package—Fig. 4—This unit prevents stream pollution . . . and provides odor abatement. It is available to war plants, air bases, army camps, naval bases and municipalities on suitable priority rating.

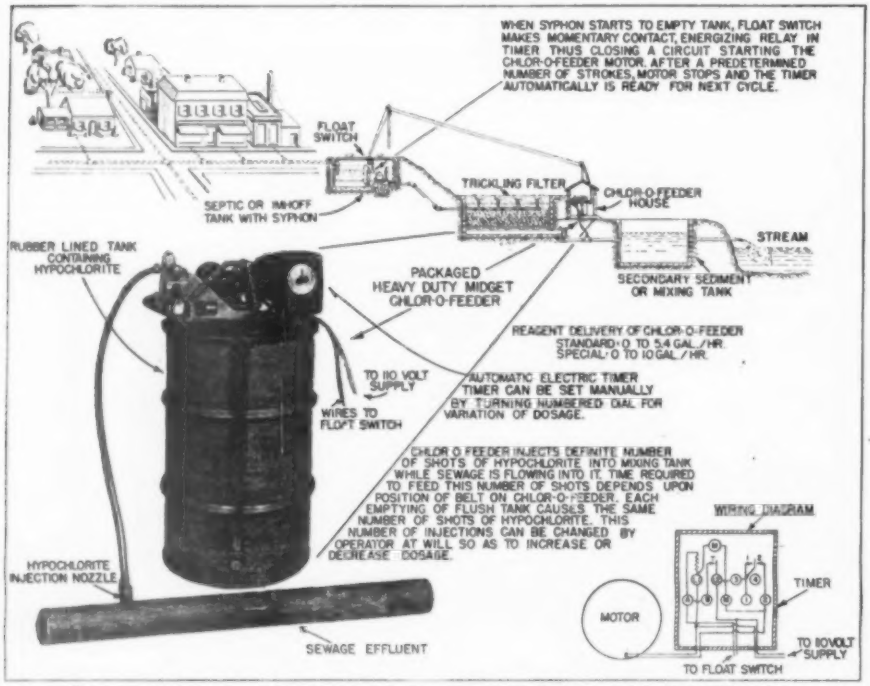
WHEN SYPHON STARTS TO EMPTY TANK, FLOAT SWITCH MAKES MOMENTARY CONTACT, ENERGIZING RELAY IN TIMER THUS CLOSING A CIRCUIT STARTING THE CHLOR-O-FEEDER MOTOR. AFTER A PREDETERMINED NUMBER OF STROKES, MOTOR STOPS AND THE TIMER AUTOMATICALLY IS READY FOR NEXT CYCLE.
FLOAT SWITCH
TRICKLING FILTER
CHLOR-O-FEEDER HOUSE
SEPTIC OR IMHOFF TANK WITH SYPHON
STREAM
SECONDARY SEDIMENT OR MIXING TANK
RUBBER LINED TANK CONTAINING HYPOCHLORITE
PACKAGED HEAVY DUTY MIDGET CHLOR-O-FEEDER
REAGENT DELIVERY OF CHLOR-O-FEEDER STANDARD: 0 TO 5.4 GAL./HR. SPECIAL: 0 TO 10 GAL./HR.
TO 110 VOLT SUPPLY
AUTOMATIC ELECTRIC TIMER TIMER CAN BE SET MANUALLY BY TURNING NUMBERED DIAL FOR VARIATION OF DOSAGE.
WIRES TO FLOAT SWITCH
CHLOR-O-FEEDER INJECTS DEFINITE NUMBER OF SHOTS OF HYPOCHLORITE INTO MIXING TANK WHILE SEWAGE IS FLOWING INTO IT. TIME REQUIRED TO FEED THIS NUMBER OF SHOTS DEPENDS UPON POSITION OF BELT ON CHLOR-O-FEEDER. EACH EMPTYING OF FLUSH TANK CAUSES THE SAME NUMBER OF SHOTS OF HYPOCHLORITE. THIS NUMBER OF INJECTIONS CAN BE CHANGED BY OPERATOR AT WILL SO AS TO INCREASE OR DECREASE DOSAGE.
WIRING DIAGRAM
TIMER
MOTOR
TO 110VOLT SUPPLY
TO FLOAT SWITCH
HYPOCHLORITE INJECTION NOZZLE
SEWAGE EFFLUENT

Fig. 4—Automatic and Proportional Treatment of Sewage with Hypo-Chlorite

Operated by remote control from Septic or Imhoff Tank with syphon, chlorinator **automatically** doses sewage as it passes from trickling filter to secondary sediment or mixing tank before final discharge to stream or river. As syphon starts to empty tank, a float switch makes momentary contact, energizing relay in timer, thus closing a circuit, starting the Chlor-O-Feeder motor. After a predetermined number of strokes, motor stops and the timer automatically is ready for next cycle.

The %Proportioneers% Chlor-O-Feeder injects a definite number of shots of hypochlorite into mixing tank while sewage is flowing into it, the time required for these injections depending upon position of belt on Chlor-O-Feeder. Each emptying of flush tank causes the same number of shots of hypochlorite. The number of these injections can be changed at will by operator so as to increase or decrease dosage.

SEWERAGE

JOINT ADMINISTRATION AND COLLECTION OF WATER AND SEWER ACCOUNTS

By LEONARD N. THOMPSON, Engineer and General Superintendent
Water Department, St. Paul, Minn.

FROM the outset of the work of the Committee on Joint Administration and Collection of Water and Sewer Accounts, it appeared that there existed a large amount of literature covering comprehensively the subject of sewer rental laws and the many types of sewer rental rate structures. Reference is made at the end of this report to several of these noteworthy publications. To those officials who are interested in the subject and wish to study forms of rate structures, the Committee suggests a review of these papers. The Committee acknowledges the use and study of these publications in the preparation of this report.

While in this report the terms "sewer rental" and "Sewer service charge" may be used interchangeably, the Committee favors the expression "sewer service charge" as more descriptive of the service rendered. This should be considered when preparing material for educational or publicity purposes. Where the sewerage system is already in existence and perhaps paid for, the owner-user sometimes wonders if the "sewer rental" charge means that he is in fact paying twice for the system.

The sewer service or rental charge method has been fairly well worked out, but its application has raised other problems in connection with administration, billing and collection. These problems have, in an increasing number of cases, fallen upon the water department. They have been described very aptly as several series of problems rather than one particular question. On general policy and administration problems little has been written, and in all the data available there has been little to indicate the best practice or to guide the executive.

With full realization that there exists a wide spread in local conditions, that laws, ordinances and local prejudices may be difficult to overcome and that definite standards, applicable under all conditions, are not now possible, it is the hope of the Committee that its conclusions may here produce discussion from which will finally develop definite recommendations to the effectual, economical and workable administrative machinery and practices. These recommendations will then be available as a guide to those now struggling to emerge from their difficulties and to those water works superintendents who suddenly find themselves confronted with the task of collecting both sewer and water charges. Only by full discussion by all those who are interested, and by exchange of information among those having knowledge and experience, can a workable outline be established for others to follow.

Water superintendents have generally hesitated to endorse the joint administration of sewer and water works. Particularly have they been skeptical of the effects on the water department of assuring the collection of sewer service charges. At the start, the difficulties appear many, and it is true that the joint administration, billing and collection of water and sewer bills introduce certain problems, but experience is showing that, with proper rules and methods of procedure, these difficulties are not insurmountable, nor do they appear to place the water department in an unfavorable position.

Sanitation and public water supply are both indispensable services in modern communities; although essentially complementary services, they have developed separately and in the great majority of cities are administered separately. The necessity for enlarged or improved sewage facilities has created new problems in financing, and, concurrently, means for more efficient administration. Not so long ago many cities were struggling under the burden of relief expenses and could not increase their bonded indebtedness. They feared to impose further increases in general property taxes. The revenue bond and service charge method of financing provided a practical solution for the many cities that were able to avail themselves of this method.

Today, with the inescapable necessity of increasing the national debt, state and municipal governments, accounting for approximately one-third of the total indebtedness, will be expected to keep expenses to a minimum. There probably will be some restraint on new issues and in this situation the adaptability of the revenue bond method will prove its worth. Financing out of revenue from service charges—the revenue bond method—which does not add to the bonded indebtedness of the municipality, has gained great favor.

The Committee has attempted to determine the effectiveness of existing legislation permitting the construction of sewerage systems and sewage disposal plants, and of the authority for bond issues, general tax levies and sewer service charges. Twenty-seven states now appear to have adequate satisfactory legislation. Eight report either no legislation at all or unsatisfactory legislation. Two states report that special enabling acts are required, and two report difficulty in the sale of revenue bonds, suggesting need for careful review by the authorities creating the power to issue bonds. In but five of the 42 states reporting did there appear to be restrictions on the creation of metropolitan districts, although a complete analysis of the state laws would have to be made and a legal opinion obtained before a conclusion could be made regarding the actual situation in any state. The fact remains that a great deal of the legislation or amendatory legislation has been passed within the past ten years, indicating the growth in sentiment for water and sanitary districts. Some of this, however, has been emergency legislation and must be given careful study before amendments are offered. While adequate legislation appears to be available in 27 states, in only a few of the states have the provisions been used to any extent.

Replies from 30 water superintendents to a questionnaire on legislation, rules and policies, indicate that the water works profession is far from agreement on its ideas concerning either rates or methods of administration.

The establishment of special boards for the joint administration of the operation of a water department and a sewage disposal plant appears to the Committee to be largely a matter for local decision. Responsibility for maintenance, operation and construction of sewerage systems and disposal works may not, properly, be of concern to the water works administration, often being delegated to other departments. The *actual control* of plant operations of water and sewerage systems under one administrative head, however, would appear to have certain distinct advantages. The *administrative functions,* including the duties of billing and collection, present problems so similar in nature and may effect such economies that control under one administrative head seems most logical and advisable.

Since a water department has already set up the machinery and facilities for both billing and collection, separation of these functions is a duplication of effort and an expense neither justified nor effectually criticized because of the added burden placed on the water works superintendent. Since, generally, those who are beneficiaries of the sewage disposal plant or sewage system of the city are water consumers, the water department already has available the most reliable and complete consumer ledger system.

There is a wide variation in the officials on whom responsibility is placed. A recent survey of 91 cities showed 14 different classifications of officials in charge of sewer systems; 13 of the 91 were water superintendents, 11 joint superintendents of both water and sewer systems. Of 94 cities surveyed, 18 held water departments responsible for sewer rental collections. Thus, it seems that the responsibility for the administration of sewer rental charges is assigned in many ways, depending upon statutory provisions, governmental organization and the basis of rental. With the increased demand for improved sanitary conditions, it is becoming customary to make the water department the responsible agency through which a financial plan and subsequent administration can be worked out.

A superintendent confronted with the problems of joint administration of the two services must, at the start, be concerned with certain definite problems:

1. The matter of legislation or statutory authority: It is highly desirable that such legislation: (1) clearly establish the administrative body and method of financing; (2) grant to such ad-

This paper was presented before the A.W.W.A., at Toronto, Canada, in 1941, by Mr. Thompson as Chairman of the Committee on Joint Administration and Collection of Water and Sewer Accounts and reproduced by permission of the Association.

ministrative body the power to adopt a rate schedule and necessary rules; (3) provide authority for the enforcement of all rules; and (4) make definite provision for the separation and disposition of all funds collected.

2. The determination of the amount of money to be raised by a sewer service charge after a policy has been established regarding the part of such charge that will be used to meet costs of operation, maintenance, betterments, extensions and debt service: When the sewer service charge is based on water consumption the superintendent can make a reasonable estimate of the probable returns. It is desirable that this sum be such that it will be reasonably constant over several years, in order to avoid upsetting charges once they are established. For this purpose it is wise to design rates that will produce a slight surplus which may be used as a cushion against increased costs of sewage treatment or fluctuation in water consumption.

3. The method of raising the desired revenue.

4. The methods of billing and collection and control or accounting.

5. The adoption, by the administrative body, of local rules and ordinances governing the matter of collections, discontinuance of service, discounts or penalties, etc.

With the present high tax rates and, in many instances, tax limitations, every means is being sought to find new sources of revenue. The primary purpose of a sewer rental fund, however, should be to provide for the proper financing of the maintenance and operating costs of the sewage system and sewage treatment works. Practice has shown a wide variation in the extent to which such revenues are relied upon to meet capital, operating and maintenance costs, but the Committee feels that consideration should be given first to the combined method of financing, i.e., assessing the cost of construction against the property benefited and making a service charge for maintenance and operation, with authority to transfer any surplus income from time to time to amortization of the funded debt. Another variation of this method is to include in the service charge the cost of the treatment but not of the sewerage system itself. The revenue bond method for the entire cost is a special consideration and not susceptible to conclusive recommendations.

Installation of a sewer system and disposal plant is beneficial to all properties, even to vacant property, by enhancement of potential values, and therefore, should be taxed for the costs of these improvements. The costs of maintenance and operation are attributable to and equitably chargeable to the users of the works. It is realized by the Committee that tax-exempt property will escape any payment of the capital costs, but legal opinion seems to indicate that sewer rental costs must be uniform and cannot be increased to the user of the system, located on tax-exempt property, when such increases are ostensibly for the purpose of collecting the equivalent of the tax item for construction.

About twenty different forms of sewer rental or sewer service charges are now existent, based upon uniform charges, the quantity of water consumed, the number and type of plumbing fixtures, the number of persons served, the type of premises, the character of the sewage, or upon a combination of one or more of the above methods. The water superintendent, as administrator of such collections, should be vitally interested in and consulted in the establishment of any sewer rental rate structure. While the burden of responsibility for the rates should remain with the sewer division or the city administration, it is highly desirable that they be made with the advice and approval of the water works executive. In establishing the basis, the portion of the total cost which can properly be borne by the city as a whole, i. e., collected by taxation, and the balance to be collected as a reasonable charge against the users, in proportion to the individual benefits derived, must first be determined.

A discussion of the many methods or bases for sewer rentals is covered in the several publications previously referred to, but a study of the many methods and the apparent trend through experience prompts the Committee to favor a charge based on the metered water consumption, either as a percentage of the water bill, or directly on a consumption basis. Directly on a consumption basis, the billing may be at a uniform rate or a step rate. A flat rate is not fair to the small consumer. A rate based on fixtures is difficult to administer. The metered-water method is the closest approximation to the use of system that is practical of application. It is dependent upon complete metering, and modifications have to be taken into account for private supplies and such industries as use large quantities of water which are not discharged into the sewer system. When the water supply is not metered, a flat rate based on the size of the water service or connection, or a charge established as a percentage of the water bill, would produce an approximation of the foregoing method.

The cities of St. Paul, Minneapolis and Detroit have sewer rentals which are typical of the three methods based, directly or indirectly, on water consumption. All three methods have been operating very successfully.

Minneapolis bills for water at the uniform rate of 7½ cents per 100 cu. ft. Sewer rental charges, which are also based on the metered water consumption, are on a sliding rate scale, as follows:

First .....100,000 cu. ft. @ 2.8c per 100 cu. ft.
Next .....200,000 cu. ft. @ 1.5c per 100 cu. ft.
All over .....300,000 cu. ft. @ 0.75c per 100 cu. ft.
The minimum bill rendered is 37 cents.

For one and two-family homes the winter quarter water consumption is used as the basis for sewer rental charges throughout the year. The owner or occupant of this type of property is thus relieved of paying a sewer rental charge on water consumed for lawn sprinkling. Large consumers, of course, receive the benefit of the sliding scale. The annual revenue from sewer rentals is designed to care for operation and maintenance, 60 per cent of the fixed charges of the treatment plant and 30 per cent of the fixed charges on intercepting sewers. The balance of the costs are raised by a mill tax.

St. Paul uses a step rate for water consumption plus a fixed or service charge based on the size of the water meter. The sewer rental charges are only indirectly based on water consumption, being based upon the size of the water meter rather than on consumption directly, as follows:

Size of Meter	Annual Water Service or Demand Charge	Annual Sewer Rental Charges
⅝ in.	$ 3.00	$ 2.40
¾ in.	4.20	3.00
1 in.	7.20	5.00
1¼ in.	10.20	9.00
1½ in.	13.20	15.00
2 in.	27.00	30.00
3 in.	60.00	75.00
4 in.	120.00	180.00
6 in	240.00	360.00
8 in.	420.00	630.00
10 in.	600.00	900.00
12 in.	.....	1,350.00

The total collections for sewer rentals are used only for costs of maintenance and operation. This city reports that the method has worked well except that, since both the service charge for water and the sewer rental charges are based on the meter size, the department has received several hundred requests for a reduction in the size of the water meters. Reductions granted have, of course, reduced both water revenues and sewer rentals.

Detroit has a three-step water rate plus a service charge based on the size of the meter. The sewer rental rate of 11 cents per 1,000 cu. ft. of water consumed is added to each step of the water rates, and water consumed is billed at the one combined rate to include both water and sewage disposal, as follows:

Water Consumption Charge	Sewage Disposal Rate Per 1,000 Cu. Ft.	Total Rate Per 1,000 Cu. Ft.
First 10,000 cu. ft. per month 78c per 1,000 cu. ft.	11c	89c
Next 900,000 cu. ft. per month 60c per 1,000 cu. ft.	11c	71c
All over 100,000 cu. ft. per month 48c per 1,000 cu. ft.	11c	59c

The service charge is added to consumption charge and all shown as one item on the bill.

In certain localities the presence of one or more industries may so affect the strength or character of the sewage, due to the degree of pollution, that some account must be taken of it in the rate structure. This is particularly true when the cost of operating a sewage disposal plant is involved. Also, in certain industries, where a large amount of water is consumed, provision may be made to discharge the industrial waste so that little if any use is made of the sewage disposal system, or even the sanitary or storm systems themselves. While some cities take no account of this factor, it seems fair to reason that, when a large percentage of the water used is not returned to the sewers, some adjustment in the sewer service charge is proper and even necessary to meet statutory requirements. While the enabling act should provide the authority for such a change, it is the opinion of the Committee that the basic charges, based on water consumption, should still be continued, and such conditions treated as special cases, making equitable adjustments in the charges, and so preserving the simplicity of the general rate structure. The enabling act should give the administration or those invested with power to establish the

rates, proper latitude to make certain uniform adjustments or exceptions to the rate structure.

Many cities are confronted with the problem of private sources of water supply, the water from which finds its way into the public sewer system. Authority for the billing of such accounts for the sewer service charge must be provided. There seems to be no reason why the same rates cannot be applied here as to users of the public water supply.

In St. Paul and Minneapolis there are 376 private wells, producing approximately 40 m.g.d. The two cities report favorably on the complete metering of the private supplies accomplished by ordinance, the sewer rental billing made in Minneapolis being on the water pumped from the private wells, and in St. Paul on the size of the meter as set on the well.

In these cities, where the private supplies have been metered for about eighteen months, it is reported that there has been no particular criticism. In both cities each case was individually investigated and the owner advised regarding type and size of meter. Perhaps the greatest difficulty experienced was the stoppage of meters due to sand pumped from the wells. In St. Paul, where the charges are based on the size of the well meter, the billing is continued until a well is reported out of service and sealed. The installations of small wel's for air-conditioning, which are not used during the winter months, are billed throughout the year.

Ordinances should provide for the registration with the billing agency of all old and new sources of private water supplies. These meters should be read and treated as any other account. Since the department has no method of discontinuing such private supplies for non-payment, provision should be made to place delinquencies on the tax rolls or to file them as a lien upon the property.

The trend toward suburban development in many cities has become a real problem. Those who move outside the corporate limits of the city for various reasons, in some cases to avoid city taxation, demand the same utility services they enjoyed in the city. When tax funds have been used to construct and maintain a sewerage system and/or a sewage disposal plant it seems unfair that such facilities should be placed at the disposal of non-residents at less than actual costs. When metropolitan districts are established to furnish utility service to such areas, it is highly desirable that sewer rental charges be increased to represent at least the equivalent amount paid by those taxpayers who are or have paid for the construction of the utilities services. The Committee feels that there is every justification for the creation of metropolitan utility districts, but where those consumers of the service are beyond the tax jurisdiction of the municipality, the payment for such service should represent at least the equivalent of the sum total payments made directly or indirectly by the consumer for like service inside the city, including all costs of amortization, interest, depreciation, maintenance and service.

The difficulties encountered in the collection of sewer service charges are not very great once a sound and workable method is adopted. Sewer bills or sewer service charges may be made separately and entirely independently of the water bill, separately and attached to the water bill, included in the amount of the water bill, or shown as a separate item on the water bill.

There is a natural antipathy among water works men toward confusing the water bill with charges which are primarily of no concern to the water department. Placing additional charges on a water bill, it is felt, will conjure up in the mind of the consumer the idea of an increased water bill. For this reason the practice of making separate bills has often been employed. The committee is of the opinion that the additional expense involved in issuing separate bills is not justified, that experience is proving that a water bill, carefully prepared and explanatory, will neither confuse the consumer nor bring undue criticism upon the water department. It is reported that during the initial stages many inquiries are received but that once the additional charge is understood, the complaints are few.

Simplicity in rate structure and in billing is highly desirable. One of the strongest arguments in favor of a rate based on water consumption is the ease with which the charge may be included with or on the water bill. The bill should be clear and should properly indicate each charge. A statement of the rate schedule is highly advisable. Proper publicity prior to the initiation of the combined method of billing and proper explanation have been found to work successfully and to overcome the fears of the superintendent. Reports indicate little, if any, increased delinquency in the payment of water bills. A printed notice on all water bills to the effect that the water department is acting only as the collection agency for sewer rental charges and that the funds are maintained separately had proved helpful in a number of cases.

Practically all public utility types of billing machines can be so constructed as to indicate the water charge and the sewer rental charges separately, and to tabulate or accumulate the two accounts separately for proper accounting purposes. This process is available even to the extent of duplicating or repeat-printing the amounts of the bill proper and on the cashier's stub. Much clerical and consumer's time may be saved and a clear record kept if all collections made are credited on the one ledger card under proper headings. Accounting control and trial balances are simplified. Separate accounting of each fund is highly desirable, and since the water department is acting only as the collection agency, the funds collected for sewer rental purposes should be credited directly to such an account and turned over to the proper authorities for disposition and disbursement. Colored ledger cards for carrying the accounts of private supplies are desirable and helpful in distinguishing the type of supply easily and quickly, without interference with the financial control system.

Some provision must be formulated in the case of delinquents. Simplicity indicates that the same discount rate or penalty should be applied to sewer and water accounts.

The water department should have the right to instigate all rules governing the method of collection, time or period of billing, to correspond with the regular water billing periods, the rules for collection of delinquent accounts, turn-off for non payment, etc. Since it is not practicable to shut off a sewer connection, the most logical and practicable method of forcing payment of sewer rental charges is to demand that they be paid with the water bill, with right to deny service of both. While on the face of it, it does not seem fair to a water department to be required to deny service to a water consumer because he refuses to pay a sewer rental charge, here again experience shows that the percentage of delinquencies is very small, varying usually from zero to 10 per cent in 37 cities, with one city reporting 20 per cent and two as high as 30 per cent in the depression period. There is no reason to believe that the sewer rental charge on a water bill has increased delinquency.

In practice it will be found that numerous accounts are not connected to the sewer system and, therefore, are not subject to the sewer service charges. In one city a charge is made where the sewer is available, irrespective of whether actual connection is made or not. In another, no charge is made until actual connection is made. In initiating the sewer rental charges in the latter city, the charge, initially, placed on all ledger accounts and billed until complaints and investigation proved the error.

When charges are based on the water consumed and allowance made for lawn sprinkling, it is the usual practice to establish, by a review of the reading sheets, the normal or average consumption for one billing period at each premise as indicated in the off-sprinkling or winter months and to indicate the amount so arrived at on the reading sheets and ledger cards as the average domestic consumption. The sewer service charge is then applied to this same consumption at each billing period. Established percentages of the water charge or fixed charges, when these methods are used, and any other information necessary to billing should be entered on both reading sheets and ledgers. The water superintendent should see to it that his department is reimbursed for all expenses incurred in carrying this added service. These costs may include additional billing equipment, the cost of changing over some equipment to meet new demands, the cost of new ledgers, a fair and proportional share of the postage, clerical and miscellaneous expenses.

The water superintendent should have the complete cooperation of the public works department, sewer department or whatever agency controls the installation of new sewer connections, in order that records may be completely and accurately up to date. Insofar as possible each department should be self-sustaining, free from any political interference and in full control of the revenue received, subject only to the limitation that they be expended for water works and sewerage services and for no other purpose.

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FINANCING SEWAGE WORKS OPERATION

A Revenue Plan That Has Worked Successfully in a Small City

By JOHN A. GOETZ
Superintendent
Water and Sewer Depts., Mattoon, Ill.

THERE are so many legal ways in which the "people" can prevent the impositions of the modern life—the construction of sidewalks, paving of streets, disposal of waste and other improvements—yet often it must be done the hard way. This applies particularly to such undertakings as sewage disposal, a very unpopular subject in certain localities, especially when politicians take up the cause and "protect" their constituents from being imposed on. It would probably be better to organize a district, particularly where territory outside the corporate limits of a city are served, but when this is not possible, a revenue method (which requires no referendum) is a way out. It is such a plan of financing, with which we are concerned.

Rate Structure

In order to set up rates sufficient to furnish income to meet operating expense, retire bonded debt and provide for depreciation of equipment, a study of water use was made. The writer had never been satisfied with a straight sewerage charge, based on water use alone. Especially of concern is the penalizing effect of a high rate for water use, for all domestic purposes, while the nominal users, living in apartments and flats, benefit at the expense of the householder. Water used for lawn sprinkling, gardens, pools, etc., never reaches the treatment plant, and any extra charge becomes a punishment for the use of water. On the other hand, the apartment and hotel dweller, especially the conservative user, will produce just as much sewage with much less water use. The study disclosed that more than three-fourths of all charges would have to be levied against homes, apartments, hotels and rooming houses and very little against industries. On account of this predominance it seemed logical to consider the individual home, or family, the unit for a basis.

It was assumed that with a house or apartment occupied by a family, or equivalent, there was no reason to take fixtures into account, unless more than one family resided there, or rooms were let. It does not matter how many baths or other appliances there are to serve the single family. However, even if there be only one bath on premises occupied by a family and roomers, or two families, then the minimum charge should increase in proportion. It can readily be seen that this will result in many higher minimum billings, than would be the case if only a regular minimum were applied to each water service. The billing for each service then will be as many times the minimum as there are family units served by same. Rooms in hotels and rooming houses are billed at one-fourth of a family unit. Private toilets in stores, offices and other establishments are treated the same as family units. Toilets accessible to the public such as in public buildings, taverns, service stations and the like take a double minimum. Any mercantile or industrial establishment is billed one minimum for private toilet and one-twelfth the minimum for each employee above four.

The minimum billing is for one month and is based on the use of 400 cu. ft. (3,000 gallons) of water use. This seems to be a fair assumption as about 85 per cent of customers come within this range. When more water is used, charges for sewerage increase at the rate of one-third of water billing, up to 1,600 cu. ft., after which the rate decreases. The step rates do not benefit the user of larger quantities of water until the minimum billing is passed.

Sounds Complicated, But Isn't

It is not so bad if you get started off on the right foot. A survey of structures and installations, and an index are necessary, but there are a number of good reasons why you ought to have that anyway. You will then know who has connections to sewers, who maintains outside toilets, who uses private wells, who has private water systems, and a multitude of things you have been wanting to know. This is also a good way to find out more about your neighbors. The Mattoon form is reproduced in Fig. 1, but would not suit you, so get up your own.

Such a survey gives all required information to set up a definite minimum for each water user, directly on the meter sheet from which billing is done. The records are kept up to date from permits issued under building or plumbing code. If another department issues such permits, duplicates of same, or periodic checking of records will not entail much work. In making the survey and index, reference should be to premises, as owners come and go, but the premises stay. Where water and sewer departments are operated jointly, there is no reason why service line records, locations, etc., can not be carried on the same cards.

Joint Billing of Water

This is not a treatise on the part of bookkeeping by a learned accountant but rather a description of a very simple method of customer billing and accounting, jointly as far as equipment, bills and ledger are concerned but separately as to water and sewer accounts. And the bills show meter readings, use, separate amounts for water and sewerage, totals, all on a lowly government post card Fig. 2.

The meter readers' sheet, Fig. 3, was set up to show the usual readings, consumption and charges for both water and sewers, with the minimums prominently placed at the head of sheet. For water, the minimum is based on meter size; for sewerage, it depends on installation, number of families, public building, etc. The operator sees at a glance whether water use or minimum applies. Post card bills are addressed by machine. Account numbers are by route number and consecutive numbers separated by a dash.

Billing Operation

Bills are arranged in route groups, totals taken for both water and sewerage and checked against audit, or proof sheet (Fig. 4), from the billing machine. This machine has a "split" keyboard enabling separate totals for water and sewerage billing and will at the same time total the two items on bill and stub. The ledger sheet, Fig. 5, is arranged in columns for use or consumption, amount of water, amount for sewer, date, meter readings, water paid, sewer paid, water penalty paid, sewer penalty paid and still a small column for remarks! No one thought of anything else to put on it.

As only from 10 to 12 per cent of bills are usually delinquent, no stubs are prepared for same at the time of billing. This is taken care of near the end of month by listing unpaid accounts for action by the collector. Incidentally the ten per cent penalty

CITY OF MATTOON—WATER & SEWERAGE DATA

STREET..... Number..... Lot..... Block..... Addition.....

WATER.. Public..... Service line size.. ..... Meter size..... Private well: Type ..... Power pump .....

SEWER Connection Direct..... Downspouts..... Drainage Dist.....
Cesspool..... Connected.....

STRUCTURES Type..... Private.....
Use..... Public .....

RATE Per month, minimum ..... Date This record.....19....
Alterations.....19....

CLASSIFICATION

DOMESTIC	MERCANTILE	INDUSTRIAL
Residential - - - - - - - ☐	Store or Office - - - - - ☐	Factory or Shop - - - - - ☐
Church - - - - - - - - ☐	Barber or Beauty Shop - - ☐	Greenhouse - - - - - - ☐
Hospital or Institution - - ☐	Garage or Service Station - ☐	Laundry or Creamery - - ☐
Hotel or Rooming House - ☐	Restaurant - - - - - - - ☐	Packing Plant - - - - - ☐
Lodge Rooms - - - - - - ☐	Tavern, Soft Drink Est. - - ☐	Poultry House - - - - - ☐
..... ☐	..... ☐	..... ☐

Public Toilets	Floor Drains	No. Family Units	No. Employees .....
Private Toilets	Slop Sinks	No. Rooms Each	No. Pupils .....
Bath or Showers	Restaurant Sinks	Hosp. or Inst. rooms	No. Inst. Occupants .....
Lavatories	Wash Racks	Hotel rooms to rent	....
Kitchen Sinks	Barber Chairs	Rooming, rooms to rent....	....

If additional data is available, list on back and check here ☐

Fig. 1. *Form for Survey Data on Water and Sewer Service*

CITY OF MATTOON—WATER AND SEWER DEPTS.

12th St. & Marshall Ave. MATTOON, ILLINOIS City Clerk's Office

"Above all, it's a safe water"

METER READINGS	
Present	Previous
147	143

This bill covers services to MAR 9
MAR 9

SYMBOLS
Wtr.—Water charge.
Swr.—Sewer rental.
Tot.—Total combined bill.

Nov. 1, 1942

10 per cent penalty will be added to and collected if unpaid by due date, November 16, 1942.

USED 100 cu. ft.	NET BILL
4	144 WTR 48 SWR 192 TOT

Nov. 1, 1942

NET BILL
144 WTR 48 SWR 192 TOT

Rates for Water Used During Each Month per 100 cubic feet.

Untreated Water		Treated Water	
For first	533 cu. ft. 31½c	For first	1,337 cu. ft. 36 c
Next	800 cu. ft. 19 c	Next	65,513 cu. ft. 13½c
Next	6,665 cu ft. 11½c	All over	66,850 cu. ft. 7½c
Next	18,666 cu. ft. 9 c		
Next	26,666 cu. ft. 8 c	Sewer Service	
Next	80,000 cu. ft. 7½c	For first	1,600 cu. ft. 12 c
Next	133,333 cu. ft. 6¾c	Next	8,400 cu. ft. 8 c
Next	266,666 cu. ft. 6 c	Next	40,000 cu. ft. 4 c
Next	800,000 cu. ft. 5 c	Next	350,000 cu. ft. ½c
All over	1,333,329 cu. ft. 4¾c	All over	400,000 cu. ft. ¼c

Minimum Monthly Bill: Water 90c; Sewer Service 48c

Bring bill with you, or inclose stub when paying by mail.

Fig. 2. Bill Showing Meter Reading, Charge for Water and Sewer Service, and Total Charge

JOHN M. RICHARDSON

1313½ BROADWAY AVE. 4-169
MATTOON, ILL.

CURB BOX LOCATION & NO. 3072

METER LOCATION 2' N of N'lk 1 E of walk

METER No.	MAKE	SIZE
606372	TRIDENT	5/8
MIN. 90	MIN. 48	

DATE	READING	CU. FT. CONSPT.	WATER CHARGE	SEWER CHARGE
JULY				
JUNE				
MAY				
APR.				
MAR. 9	14762	4	1.44	48
FEB. 9	14322			
JAN.				
DEC.				
JULY				

If Lost Return to Water Department, City of Mattoon.

Fig. 3. Meter Reader Sheet. (Entry Spaces Are Provided for 24 Months)

CITY OF MATTOON WATER AND SEWER DEPARTMENTS

JOHN M. RICHARDSON

1313½ BROADWAY AVE. 4-169
MATTOON, ILL.

USED	AMOUNT WATER	AMT. SEWER	DATE	READINGS	PAID WATER	PAID SEWER	PAID PENAL-TIES WATER	PAID PENAL-TIES SEWER	Re-marks
4	144	48	MAR 9	147	144	48			

Fig. 5. Ledger Sheet. (Sixteen Entry Lines—Same Form on Reverse Side)

(*Continued on page 171*)

Audit Sheet (Posting)

MAR 9 SWR
00
TAX
00

MAR 9	90	48	09	04
MAR 9	1 80	60	18	06
MAR 9	2 16	72	21	07
MAR 9	90		09	
MAR 9	1 80			
MAR 9	1 80	60	18	06
MAR 9	3 60	1 20	36	12
MAR 9	2 88	96	28	09
MAR 9	1 08	48	10	04
MAR 9	2 52	84	25	08
MAR 9				

SWR

19 44 1 74

TAX

5 88 56

Shows separate totals for water, water penalty, sewer and sewer penalty.

Fig. 4. Audit Proof Sheet from Billing Machine

Audit Sheet (Billing)

	MAR 9		WTR
	MAR 9		00
	MAR 9		O/C
	MAR 9		00
	MAR 9		TAX
	MAR 9		00
	MAR 9		SWR
	MAR 9		00
	MAR 9		RDG
	MAR 9		00
			00 TOT
4 27	4 24		
	MAR 9	3	1 08 WTR
	MAR 9		48 SWR
			1 56 TOT
6 75	6 70		
	MAR 9	5	1 80 WTR
	MAR 9		60 SWR
			2 40 TOT
1 83	1 81		
	MAR 9	2	90 WTR
	MAR 9		48 SWR
			1 38 TOT
1 24	1 16		
	MAR 9	8	2 88 WTR
	MAR 9		96 SWR
			3 84 TOT
1 33	1 22		
	MAR 9	11	3 96 WTR
	MAR 9		1 32 SWR
			5 28 TOT
	MAR 9		WTR
	MAR 9	29	10 62
	MAR 9		O/C
	MAR 9		00
	MAR 9		TAX
	MAR 9		00
	MAR 9		SWR
	MAR 9		3 84
	MAR 9		RDG
	MAR 9	15 42	15 13
			00 TOT

Shows separate totals for water, sewer, 100 cu. ft. consumption

Fig. 6. Posting Audit Sheet

SPECIAL SEWER SERVICE CHARGES FOR INDUSTRIAL WASTES

By GEORGE E. SYMONS[1]
and
FREDERICK W. CRANE[2]

Buffalo Sewer Authority, Buffalo, N. Y.

THE cost of operation and maintenance of any sewage treatment works or disposal plant is directly affected by the quantity, character and strength of the sewage. From this basic fact stems the theory that the fairest and most just distribution of payment for the costs of sewage treatment is the sewer rental system where the user pays for services rendered proportional to the benefits derived.

The volume of water used by a service is generally the basis for sewer rentals. Industrial waste studies, however, have indicated that the concentrations of wastes discharged from certain industries into a sewer system are extremely disproportionate to the average for an entire city. Such industries, therefore, when paying sewer rental charges based on volume of wastes alone, do not adequately pay for their share of the cost of treatment of such wastes. Consequently the development of a special rate of charge for such industries based on both the volume and strength of wastes appears proper and just. A formula for such a special charge is developed and described herewith.

Buffalo, N. Y., Sewer Rental Provisions

The state of New York has authorized sewer rentals based on water consumption, fixtures, "or upon any other equitable basis." Chapter 870 of the Laws of 1939 of the State of New York covers the creation of the Buffalo Sewer Authority and repeats the above provision. Under this provision the schedule of sewer rents for Buffalo was drawn and adopted to provide that 45 per cent of the revenue was obtained from assessment against real estate and 55 per cent was to be collected on the basis of water consumption at a rate equal to 40 per cent of the cost of water. It was further provided that where water measured by a meter does not enter the sewer system the sewer rent was to be based on the quantity of water actually entering the sewer system and so determined.

In addition, the sewer rental schedule contained the following provision for special charges: "In event a lot, parcel of land, building, or premises discharges into the sewerage system sewage or other wastes which in the opinion of the Buffalo Sewer Authority contains unduly high concentrations or any substances which add to the operating costs of the sewage disposal works, then the Authority may elect to establish special rates of charge, based on the quantity of these substances, which rate of charge may be established in such a manner as the Authority may elect, or it may elect to exclude such sewage or trade wastes from its facilities."

From these provisions came two problems which confronted the Sewer Authority in regard to sewer rental charges to industrial establishments. The first of these problems arose from the protest by industries against paying sewer rental charges for water not reaching the sewer system, either due to its absorption in industrial processes, its discharge into available water-courses, or the absence of sewerage facilities. The second problem covered the supplementary charge for wastes disproportionately costly to treat.

In handling the first problem, a survey was made of all properties concerned. Where there was no sewer the matter was simple; no rental charge was made. Where water was consumed in productive processes or otherwise used up and not discharged, the attempt was made by a rational analysis to determine the average amounts so used and establish therefrom a proportion of the water consumption on which the rental charge was to be based. Little trouble was experienced with this procedure, it being generally acceptable to industry.

Each year a survey has been made of all accounts upon which the established reductions were based. These reductions have been in effect for nearly five years and no general field check has yet appeared necessary.

Somewhat as an integral part of this program has been the establishment of rental charges for water obtained from a source other than the municipal supply. Sewer rental is charged for this water at the same rate as for city water. Industries obtaining water from wells or streams are required to install and maintain meters which are read by the Sewer Authority.

Industrial Waste Survey

As an attack on the second problem, a survey of industrial establishments was made. The first step was to list all industrial concerns in the city employing more than 40 persons. There were 428 separate establishments so listed. These were divided into classes or categories according to the type of manufacturing plant or product. Twenty-seven separate classes of industries were set up. By careful consideration of these types it was possible to pick out 17 classes of industry which might discharge industrial wastes other than of sanitary character. In order of importance these were meat packers, rubber products, rendering, tanneries, breweries and malt producers, dairies, laundries, several chemical or metal industries, and others of less importance.

Each concern, 234 in all, in these groups of industries with possible industrial wastes was visited by a field engineer who obtained pertinent information concerning operations and wastes produced. These data were set forth on forms prepared for the purpose with special forms for certain industries such as the packing plants, tanneries, breweries, creameries, etc. From these data, the industries contributing the greatest waste load were determined. Samples were taken in many plants typical of a group. Other plants were sampled for a period of time, still others had been sampled in the previous years during the design and construction of the treatment works. From an analysis of the samples, the concentrations of the wastes of these industries were determined.

It was ascertained that whereas the relation of concentration to volume was disproportionate in the case of milk wastes the quantity of these wastes was too small to be of any great burden on the treatment works. Other industries, too, appeared not to warrant any special consideration as to charges, but in the case of meat packing, tanning, and rubber reclaiming it appeared that the application of special treatment charges was warranted.

Although no case is known of the application by any other city of a general formula for special sewage treatment charges of the type here considered, there are, however, numerous instances reported in the literature, where industries do pay a proportionate share of the cost of operation of the treatment works because of their excessive waste load. This instance, however, appears to be the first where a formula has been proposed for application to all industries within a municipality.

Basis for Special Charges

The Buffalo sewage treatment works is operated for the purpose of disposing of sewage and wastes in such manner as to eliminate nuisance in the Niagara River. The work which constitutes this disposal includes pumping, disinfection by chlorination, removal of solids, and the disposal of solids by digestion, dewatering, and incineration. Costs of the operation may be allocated to overhead, pumping, treatment (including sedimentation, chlorination and sludge disposal), and maintenance and repairs. The principal items of treatment cost are the cost of chlorine and the cost of chemicals and power for the disposal of solids.

Every water user paying sewer rental charges on the basis of the volume of water discharged by him into the sewers, presumably pays his proportionate share of the overhead, pumping, maintenance and repair, and normal treatment costs at the sewage treatment works. Therefore, any additional charge for service because the strength of an industrial waste is in excess of the average strength of normal sewage should be only for the purpose of reimbursing the treatment works for the extra cost entailed in the treatment of such excess waste load. The extra cost can be definitely assigned to excess chlorine consumption and to excess chemicals and power used for the disposal of solids. The quantities of these materials required in excess of the normal sewage requirements can be ascertained for an individual waste by analyzing the waste to determine its chlorine demand and its suspended solids content.

Utilizing the above established principle that additional special charges should be based only on the extra cost of treatment of excess waste loads, the following considerations entered into the development of a general formula for the determination of such

[1]Former Chief Chemist, Buffalo Sewer Authority—Now Associate Editor, *Water Works and Sewerage*.
[2]Structural Engineer, Buffalo Sewer Authority.

charges applicable to all industries. As indicated this formula should be based on the chlorine demand and suspended solids content of the particular waste, and on the cost of chlorine and on the cost of chemicals and power for the disposal of solids. The formula will, therefore, be such as to take cognizance of any change in the character of the waste discharged by any industry as well as of any change in the cost of operation of the treatment works. Consequently, periodic sampling and analyses of all wastes subject to special charges may be necessary to establish their average chlorine demand and suspended solids content. Finally, the formula should be such as to develop a rate of special charge which will be applicable to the volume of the wastes.

Derivation of General Formula

The approach to the derivation of the formula is given in the following steps:

1. Develop the formula to calculate special charge rate (R) in cents per volume unit of 1,000 cu. ft. of waste.

2. Assert the principle that water user is entitled, through payment of ordinary sewer rent, to concentrations of chlorine demand and suspended solids as normally present in sewage received at the treatment works, but that water user must pay for chlorine demand and suspended solids in his wastes above such normal concentrations. Therefore, introduce into the formula differences between concentrations of chlorine demand and suspended solids in the waste and concentrations of like substances normally present in sewage.

3. The difference between chlorine demand of waste and chlorine demand of normal sewage, reduced to pounds per 1,000 cu. ft. of waste by multiplying the concentration difference by a factor (F), is the excess chlorine demand per volume unit of waste for which the special charge should be made.

4. The difference between the amount of suspended solids in waste and suspended solids in normal sewage, reduced to pounds per 1,000 cu. ft. of waste by multiplying the concentration difference by factor (F), is the excess suspended solids per volume unit of waste for which the special charge should be made.

5. To obtain special charge rate (R), the pounds of excess chlorine demand per volume unit of waste is to be multiplied by the cost of chlorine per pound (Pc), and added to the pounds of suspended solids per volume of waste multiplied by the cost of disposing solids (Ps), i.e., cost of chemicals and power for chemical conditioning and incineration, exclusive of overhead.

6. The general formula applicable to all concerns and to all industries thus becomes:

$$R = FPc\ (C - Nc) + FPs\ (S - Ns)$$

Where R = rate of special charge in cents per 1,000 cu. ft. of volume of waste.

F = factor for converting parts per million to lbs. per 1,000 cu. ft.

Pc = contract price of chlorine in cents per lb.

C = concentration, in parts per million, of chlorine demand of the waste.

Nc = normal dry weather chlorine demand of raw sewage in parts per million of sewage as received at the treatment works.

Ps = cost in cents for chemicals used in sludge conditioning and for power for disposal of solids resulting from one lb. of suspended solids received in the raw sewage at the sewage treatment works.

S = concentration, in parts per million, of suspended solids of the waste.

Ns = normal grit-free suspended solids in parts per million of raw sewage as received at the treatment works.

The factor Pc may vary from year to year according to the contract price for chlorine and the factor Ps may vary according to the costs of chemicals and power involved in the disposal of solids as determined from operations for the previous year or previous two years. The factors C and S may be established by analyses (periodic or otherwise) to obtain average concentrations to be applied for any agreed length of period.

Determination of Values of Factors in Formula

1. Inasmuch as 1,000 cu. ft. equals 62,400 lb., one ppm. equals 0.0624 lb. per 1,000 cu. ft. Therefore, F = 0.0624.

2. The 1942-43 contract price of chlorine is $43.60 per ton or 2.18 cents per pound. Therefore, Pc = 2.18.

3. Concentration of chlorine demand (C) in ppm. in industrial waste is to be determined by standard methods of analysis.[1]

4. Chlorine demand of raw sewage or normal dry weather flow averages 5.6 ppm.[9] Therefore, Nc = 5.6.

5. Cost of disposing of solids is based on incoming grit-free suspended solids. Grit-free sewage contains none of the grit from streets washed by storms and represents approximately normal suspended sewage and waste solids as received at the treatment works. Treatment works studies at Buffalo indicate approximately 25 per cent of the total power consumption is for incineration operations. Buffalo data for years 1939-40 and 1940-41 were averaged to give representative basis for cost determination as follows:

Year	Sewage Flow M.G.D.	Grit-Free p.p.m.	Susp. Solids Lb./Yr.	Cost of Chemicals for Sludge Conditioning Per Year	Cost of 25% of Power Used Per Year
1939-40	135	157	.....	$21,160.66	$11,712.68
1940-41	140	158	.....	18,382.43	13,069.89
Average	137.5	157.5	65,923,700	19,771.54	12,391.28

$$\text{Therefore, } Ps = \frac{\$19{,}771.54 + 12{,}391.28}{65{,}923{,}700} = \$0.000488 = .0488 \text{ cents}$$

6. Concentration of suspended solids (S) in ppm. in industrial waste is to be determined by standard methods of analysis.[1]

7. Suspended solids in grit-free sewage average 157 ppm. Therefore, Ns = 157.

When these factors for present costs and sewage concentrations are applied the general formula takes the following form:

$$R = 0.136\ (C - 5.6) + 0.00305\ (S - 157)$$

Thus it is seen that, in the application of the formula under present Buffalo conditions, the special charge rate per 1,000 cu. ft. of wastes would be 0.136 cents for each part per million of chlorine demand and 0.00305 cents for each part per million of suspended solids above the normal concentration of each in the raw sewage as received at the treatment works. It is to be especially noted that the industrial waste load is included in the normal concentration values of 5.6 ppm. for chlorine demand and 157 ppm. for suspended solids content of the sewage as received at the treatment works.

There may be special cases to consider in the application of the formula. Some industrial wastes may change characteristics when diluted with a relatively large volume of sewage. In such cases the total daily chlorine demand and suspended solids loads may decrease, or increase. The change may be shown by experimental tests on mixtures of the waste and sewage prepared in the ratio of their respective volumes.

Where experimental evidence shows the chlorine demand and suspended solids load to decrease or increase on dilution, the equivalent value or effective concentration of this decreased or increased load in ppm. concentration may be calculated for the original waste. On negotiation with the company concerned it may be agreed that the equivalent concentration of the waste is to be used in the formula for determining the special sewer rental rate. In cases of this kind, frequent analyses and experiment should be made to establish the validity of the concentration used.

Suggested Limits for Application of Special Charges

It does not appear economically feasible to apply a special charge when the rate is less than 1 cent per 1,000 cu. ft. of volume of waste. From considerations of the amount of work involved, it would also appear evident that it is not economically worth while to make special charges in any case where the total reimbursement does not cover by a considerable margin the cost of investigations and necessary bookkeeping.

On the basis of Buffalo's current costs, if suspended solids were not present in a waste, the concentration of chlorine demand would have to be 13 parts per million (2.3 times the present normal sewage value of 5.6 parts per million) to produce a special charge rate or R value of 1 cent per 1,000 cu. ft. Likewise, if chlorine demand were absent, the suspended solids content of a waste would have to be 485 p.p.m. (approximately three times the present normal sewage value of 157 p.p.m.) to produce a special charge rate or R value of 1 cent per 1,000 cu. ft. It is obvious that smaller concentrations of these items when in combination with each other will produce a value for R of 1 cent or more.

The Grease Problem

Despite the fact that the Plumbing Code of the City of Buffalo expressly forbids and prohibits the discharge, without prior treatment, of any grease, fats, oils, etc., into the sewer system, accumulations of such materials are found in the sewers and to appear at the treatment plant.

The presence of grease, fats and oil in sewage reaching the treatment plant is objectionable since these materials form trou-

blesome scum in channels and on sedimentation tanks interfere with biological processes, and cause problems of excessive heat on incineration. Although they add to the complication and cost of handling and disposing of solids, nevertheless it does not appear possible to determine the direct added treatment cost due to their presence in the sewage, except as they are included, at least partially, in the suspended solids.

The tendency of grease, fats and oil to clog the sewers is also a highly objectionable characteristic of these materials. Wherever the source of these materials in sewers is ascertainable, it is possible to determine the cost of cleaning the sewers whose clogged condition is directly attributable to these wastes. However, it is quite evident that some accumulation of these materials likewise occurs throughout the length of the dry-weather sewer system and causes troublesome conditions at weirs, siphons, etc. No direct cost can be assigned to remedying these latter conditions.

Summary

From the standpoint of feasibility of application and of effecting an equitable distribution of costs of treating excess waste loads, it has appeared possible to develop and apply a general formula for special rates of charge to any industrial plant whose waste load has a concentration measured in chlorine demand or suspended solids content of approximately three times that in the sewage as now received at the Buffalo treatment plant. This general formula is such as to permit adjustments of the special rates at periodic intervals accordingly as variations in the concentration of the waste received from an industrial concern or as variations may occur in the costs of treating such wastes.

It is proposed that the application of special rates of charge as developed from the general formula be made in the same manner as normal sewer rental charges, except that the special charges be separately billed. Under this procedure, periodic sampling and analysis of the wastes of the individual concerns may be necessary to maintain the rates of charge on an equitable basis. This will serve both as a protection to the interests of the Authority and to avoid penalizing an industrial plant which improves the character of its wastes. The choice of periodicity of sampling and the extent of sampling may be left to negotiation.

There appears to be no direct way in which a special rate of charge can be determined to cover the costs caused by the discharge of grease into the sewers. It has been recommended that provision be made to charge any concern for the cost of cleaning a sewer or sewers when the clogged condition of the same is directly attributable to the wastes discharged into the sewers by such concern. This provision should be broad enough to cover other materials which also tend to obstruct the sewers.

Whereas the formula herein described has been developed for application to the specific case of Buffalo, N. Y., where disposal consists of primary sewage treatment and disinfection with incineration of solids, there seems to be no reason why the same general type of formula could not be developed in any municipality for any type of sewage treatment and problem involved.

REFERENCES

(1) Standard Methods for the Examination of Water Sewage. 8th Ed.

(2) G. E. Symons, R. W. Simpson, & S. R. Kin, "Variations in the Chlorine Demand of Buffalo Sewage," Sewage Works Journal 13, 249-64 (1941).

SIZE AND SLOPE OF SEWERS

By Simplified Formulae Approximating Kutter's

By BENJAMIN EISNER, Chief Engineer
Clay Sewer Pipe Association, Pittsburgh, Penna.

KUTTER'S formula for computation of flow velocities in open channels is preferably solved by graphs to avoid the lengthy arithmetic necessary to compute "C." Because pipe sewer problems are but a small portion of the wide field of application of the Kutter formula, and since extreme precision is not warranted in sewer and drain design, it is possible to approximate the Kutter formula for such problems by matching a simple curve to the complex one expressed by the formula. Such matching is possible only because short lengths of the curves are used. For sewers and drains "n" is usually taken at either 0.013 or 0.015; "v" is required to exceed 2 feet per second, pipe diameters generally fall between 8 and 36 inches, and slope rarely reaches 10 per cent grade.

If within these limitations, values for "s" are plotted against "d" for any given velocity, the resultant curve closely approximates a hyperbola. If too, for later convenience, "s" is measured in feet per thousand, and "d" in inches of diameter, the hyperbolic curves may be expressed in the following manner:

For "n" = 0.013: $v = 1/2\sqrt{s}\ \sqrt{d-4.5}$ (A)

For "n" = 0.015: $v = 4/9\sqrt{s}\ \sqrt{d-5}$ (B)

Of course, both cases apply only to pipes running full or half-full. Accuracy of results by use of these approximations is indicated in tables I and II which cover the range of application outlined above.

Use of these approximations with a slide rule is believed to be quite as rapid as use of charts for the solution of Kutter's formula. Although there is a slight loss of accuracy, the error thus introduced is less in amount than the errors accompanying estimates of future flow and choice of coefficient "n."

So far, no mention has been made of the term Q as used in $Q = Av$. If Q is measured in million gallons daily, if "d" is used as before, to denote pipe diameter in inches, and if the pipes are considered to run full, $Q = Av$ can be reduced to

$$d = 17\sqrt{\frac{Q}{v}} \qquad (C)$$

which is easily converted to a form suitable for rapid determination of pipe size for minimum self-cleaning velocity. If velocity of two feet per second is the lower limit, this expression reduces to $d = 12\sqrt{Q}$, for full flow, which can be further simplified by expression as "diameter in feet for 2 feet per second velocity equals the square root of the full flow in millions of gallons daily." Similarly the previous approximations for "s," at 2 feet per second velocity reduce to the fllowing—

For: $(n = 0.013)\quad s = \dfrac{16}{d-4.5}$ For: $(n = 0.015)\quad s = \dfrac{20}{d-5}$

Thus for minimum self-cleaning velocities determination of diameter and slope is rapid.

Commitment to memory of approximatoins (A) and (C) permits rapid sewer and drain design when flow charts are not readily available. For the slight loss of accuracy, speed and convenience are gained. In practical use "d" is assumed and approximate "v" determined as in (A).

This value is substituted in (C) and the result "d" is compared with the assumption. With slight practice the second trial value of "d" will be found to satisfy both equations within practical limits.

Comparison of Velocities of Flow in Conduits (Running Full or Half Full) Computed by Approximate Formula and Kutter's Formula

TABLE I (n=0.013)

SLOPE (Feet per 1,000 ft.)	DIAMETER (Inches) 8	12	18	27	36
0.1			**1.9** 1.8	**3.3** 3.3	**4.6** 4.6
1	**6.0** 6.0	**1.6** 1.6	**1.8** 1.8	**2.4** 2.5	**3.0** 3.0
3	**1.6** 1.7	**2.8** 2.8	**3.2** 3.2	**4.1** 4.3	**5.2** 5.2
10	**3.0** 3.2	**4.3** 4.3	**5.0** 5.0	**7.5** 7.6	**9.5** 9.6
30	**5.1** 5.5	**7.5** 7.5	**10.1** 10.1	**13.0** 13.5	
100	**9.4** 10.0	**13.7** 13.5			

TABLE II (n=0.015)

SLOPE (Feet per 1,000 ft.)	DIAMETER (Inches) 8	12	18	27	36
0.3			**0.9** 0.9	**1.3** 1.3	**1.4** 1.4
1	**0.6** 0.6	**1.2** 1.1	**1.6** 1.5	**2.1** 2.1	**2.5** 2.5
3	**1.3** 1.4	**1.9** 1.9	**2.9** 2.7	**3.6** 3.6	**4.3** 4.4
10	**2.4** 2.6	**3.4** 3.6	**5.0** 4.9	**6.6** 6.6	**7.9** 8.1
30	**4.2** 4.5	**5.9** 6.2	**8.8** 8.5	**11.4** 11.2	**13.6** 13.8
100	**7.7** 8.2	**11.7** 11.3	**16.9** 15.5		

Bold face figures indicate approximation. Light face figures are results from chart of Kutter's Formula.

AN IMPROVED METHOD OF VELOCITY CONTROL IN GRIT CHAMBERS

By RALPH J. BUSHEE, Designing Engineer
Chas. W. Cole & Son, South Bend, Ind.

Part I—Method of Velocity Control

THE problem of designing a grit chamber with a control section that will give a constant velocity at all flows is essentially that of making the shape of the depth versus cross-sectional area curve of the grit chamber fit the depth versus quantity/velocity curve of the control section. The earlier approach to this problem consisted in the development of the so-called proportional weir, which had a straight line depth-quantity characteristic as is needed with grit chambers of rectangular cross-section. While the velocity control obtained by this method has been satisfactory, there is a disadvantage in that for proper operation of the weir, the entire head in the grit chamber must be lost.

In order to make use of control sections, such as the Parshall and Venturi flumes, which require a smaller loss of head for their operation, Camp[1] and Holmes[2] have proposed that the shape of the grit chamber be adapted to fit the head-quantity curve of the control section. By this method it is possible to reduce the loss of the head to as little as one third of the depth of flow in the grit chamber. The disadvantage of this method is that the resulting cross section is not the most economical one to build, and moreover, it is not well adapted for most mechanical cleaning mechanisms. The slope of the side walls may be quite flat in some cases. Barker[3] has suggested that this last difficulty could be solved by building two or more chambers for one control section.

A Proposed Method

There is, however, a third solution to this problem which makes it possible to use a grit chamber with a rectangular cross section in conjunction with a flume, or any other control section for that matter, and still get a velocity which is very close to that desired over a wide range of flows.

This method consists essentially in determining the relationships so that the straight line depth versus cross-sectional area curve of the rectangular grit chamber lies as closely as possible to the depth versus quantity/velocity curve of the control section, over the range of flows being considered. To accomplish this, two relationships must be determined; first, the ratio of the width of the grit chamber to the width of the control section which gives the closest average slope of the two curves; and secondly, the relative elevations of the bottoms of the control section and of the grit chamber which result in the closest position of the two curves. The determination of these two relationships can best be made graphically and the curves of Fig. 1 are used for the solution with a free-flowing venturi flume. It will be understood that the method is perfectly general and can be used for any type of control section for which a curve can be drawn.

A Specific Example

The formula for the flow through a rectangular free-flowing Venturi flume is

$$(1)\quad Q \equiv 3.09\ b\ H^{3/2}$$

where "Q" is the flow in second feet, "b" is the width of the flume in feet, and "H" is the total energy head (depth plus velocity head) above the flume.

The middle curve in Fig. 1 is for the above formula with $b = 1.0$. In order to be able to determine the velocity limits within which we are working, curves of 0.95 Q and 1.05 Q are also shown.

As an example, assume a grit chamber 4 feet wide with a maximum capacity of 8 m.g.d. or 12 sec.-ft. At 1 foot per second velocity the depth at maximum flow would be 3 feet. Lay a triangle tangent to the lower curve and at such an angle that the difference in ordinates between the point where the edge of the triangle cuts the OY axis and the point where it intersects the upper curve is 3 feet. The point where the straight edge cuts the OY axis, in this case 0.62 feet, is the distance that the bottom of the flume must be below the bottom of the grit chamber.

To determine the required width of the control section, draw a line through the zero point parallel to the above line. A point on this line is $E = 1.0$ and $Q/b = 6.7$. Thus with a foot in the grit chamber, corresponding to 1.62 feet total energy head on the flume, a flume 1 foot wide will pass 6.7 sec.-ft. Since the amount required for the assumed grit chamber 4 feet wide is 4.0 sec.-ft., the width of the flume should be 4.0/6.7 of 1 foot or 0.597 foot, or 7.15 inches. It will be noted that between depths of 0.4 and 3.0 feet in the grit chamber (heads of 1.0 and 3.6 on the flume), corresponding to flows between 1.1 and 8.0 m.g.d., the theoretical velocity through the grit chamber will be between 0.95 and 1.05 feet per second. This range of flows, with the maximum of seven times the minimum, is sufficient for most conditions.

Correction for Fillets

Most grit chambers have fillets at the bottom. With hand cleaned grit chambers this allows the cross-baffles, or other means of demarcation of the grit storage space, to be removed for the manual cleaning of the chambers. With mechanically cleaned chambers it allows the installation of cleaning devices with scrapers or buckets shorter than the width of the chamber. Where such sloping sections are installed it is merely necessary to maintain the total cross sectional area of the grit chamber below the top of the fillets.

Thus in Fig. 2 the areas omitted (1 + 2) must be equal to (3), the area added. The cross-sectional area of the original grit chamber below the top of the proposed fillets is $b \times d$. The area of the new section below the same line is $ab - ac = a(b - c)$. Equating these and solving for $(a - d)$, which is the distance that the bottom of the new section must be lowered, we obtain

$$(a - d) = \frac{ac}{b}$$

Returning to the example employed, suppose that it is desired to install fillets 0.75 foot wide (c) and 1.0 high (a). Then it will be necessary to lower the bottom of the grit chamber in respect to the bottom of the flume by $\frac{0.75 \times 1.0}{4.0} = 0.19$ foot.

And the bottom of the control section will be $0.62 - 0.19 = 0.43$ foot below the bottom of the grit chamber.

After the control section has been determined, it is well to check the design computations to see what velocity may be expected.

Table 1
Velocities Through Grit Chamber

Flume		Grit Chamber		
Total Head, Ft.	Flow, Sec.-Ft.	Water Depth, Ft.	Cross Section Area Sq. Ft.	Velocity, Ft./Sec.
0.93	1.79	0.50	1.44	1.24
1.43	3.16	1.0	3.25	0.97
1.93	5.09	1.5	5.25	0.97
2.43	7.05	2.0	7.25	0.97
2.93	9.32	2.5	9.25	1.01
3.43	11.9	3.0	11.25	1.03

Note that the introduction of fillets has increased the velocity at the 0.5-foot depth in the grit chamber. Without fillets the velocity at this depth would have been 1.08 feet per second. However, the results are close enough for this case, and in cases where they are not, the design can usually be improved with a little cut and try.

Part II—The Control Section

Sections Considered

Theoretically, any control section for which a head flow curve can be drawn can be used with the above method. From the standpoint of construction, however, the Parshall and the rectangular Venturi flumes offer advantages.

The Parshall flume would at first sight appear to be the ideal section to use, as it has a solid background of experimental data, and is made with plane surfaces which permit of easy construction. Unfortunately, however, the maximum depths commonly used in the design of grit chambers are beyond the range of the experimental data available for Parshall flumes. There is also some difficulty in interpolating smaller sizes of Parshall flumes which are of somewhat different shapes. This difficulty could be solved by making the width of the grit chamber correspond to that of one of the standard flumes.

If a Parshall flume is used, it is to be noted that the head

given in the formula is not the total head above the flume, as in some cases the velocity head at the point of measurement is a considerable proportion of the total head.

Free Flowing Venturi Flume

Where there is sufficient loss through a Venturi flume to allow it to occur, the quantity passed by the flume will be the maximum possible for the total head available. The flume is then said to be free flowing and formula (1) will apply. In general, free flowing conditions may be assumed in a Venturi flume when the loss of head is not less than one-third of the total head above the flume. The formula is a rational one and is obtained as follows:

$$(2)\quad Q = b d_t V_t$$

$$(3)\quad d_t + \frac{V_t^2}{2g} = H$$

(by Bernoulli's theorum neglecting friction)

Where Q, H and b are as previously given, and d_t and V_t are depth and velocity respectively at throat of flume.

Solve for V_t in (3); substitute it in (2); solve for dQ/dd_t, and equating it to zero, derive $d_t = \frac{2H}{3}$

as the condition giving the maximum value of Q.

Substituting 2/3 for d_t in (2) and (3), solving for V_t in (3) and substituting in (2) gives

$$(4)\quad Q = \frac{2}{3}\left(\frac{2g}{3}\right)^{1/2} b H^{3/2} = 3.09\, b\, H^{3/2}$$

It is reasonable to suppose that the shortest possible transition section ahead of the throat which would avoid a too abrupt change in flow conditions would be the one in which the slope of the water surface was uniform.

In addition to the definiations given above, let "mb" equal the width at a section at a distance of "nL" above the throat, "h" the water depth at this section, and "L" the length of the section between the grit chamber and the throat of the flume (Fig. 3).

$$\text{Then (5)}\quad h = 2/3H + 1/3H\frac{nL}{L}$$

$$= \frac{H}{3}(2+n)$$

$$(6)\quad H = h + \frac{v^2}{2g}$$

$$(7)\quad V^2 = \frac{Q^2}{m^2 b^2 h^2}$$

and (4) $Q = 2/3\ (2/3g)^{1/2} b H^{3/2}$

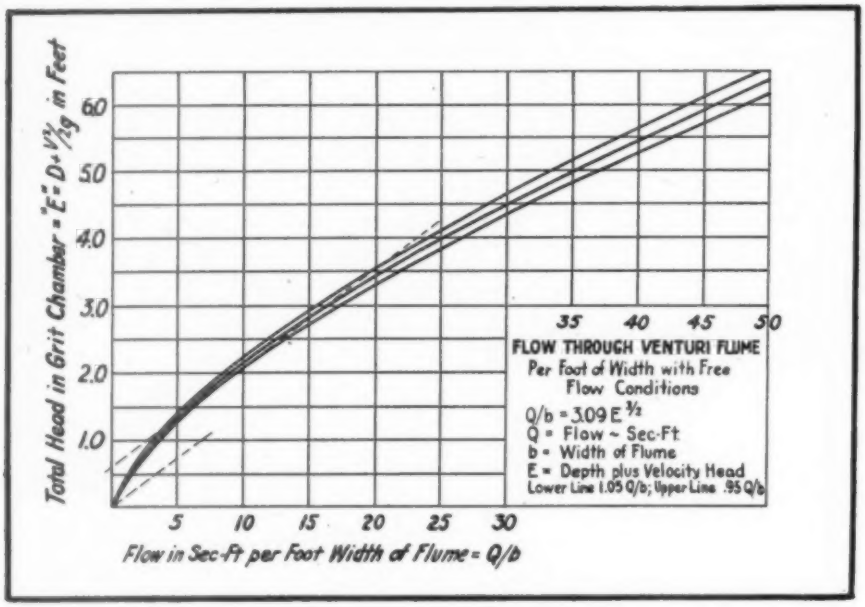


Fig. 1—Flows per Foot of Width of The Venturi Flume for Various Heads.

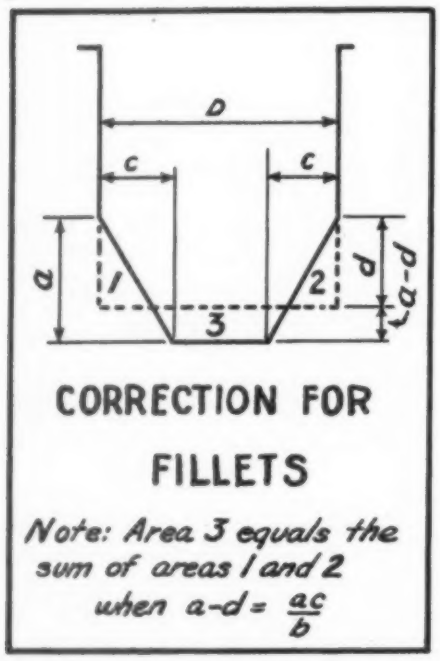


Fig. 2—Method of Correcting for Fillets in Design.

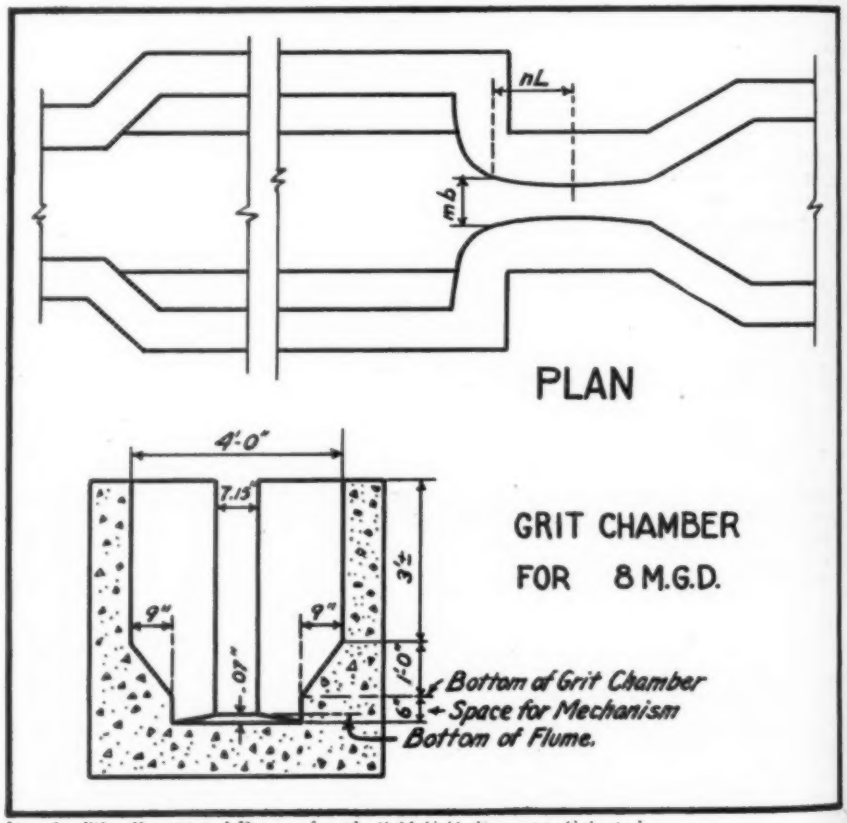


Fig. 3—The Completed Design for the 8 M.G.D. Example Selected.

Substitute these values of h, V and Q in equation (6) and the equation reduces to

$$(8)\ m = \frac{2}{(1-n)^{1/2}(2+n)}$$

The following table gives the relationship expressed in the above formula:

TABLE 2

Factors for Designing a Flume with Uniform Slope of Water Surface

n = Factor for Distance Above Throat	M = Factor for Width of Section
0	1.0
0.1	1.005
0.2	1.02
0.3	1.04
0.4	1.08
0.5	1.13
0.6	1.22
0.7	1.35
0.8	1.60
0.9	2.18
1.0	∞

Returning to the example employed, suppose we assume that the length of the transition section will be the equal to two-thirds of the maximum assumed depth of flow, or 24 inches. This will correspond to a maximum water surface slope of 3 to 1, as the depth at the throat will be two-thirds the head in the grit chamber. Also assume a length of throat of 0.2 of the depth, or 7.2 inches. Assume the return section with the same 3 to 1 surface slope. Then, since the minimum loss of head that we have assumed is equal to the velocity head at the throat section, it does not appear necessary to be concerned with the recovery of this velocity head. Make the return section 18 inches long, which allows for a theoretical recovery of 50 per cent of the velocity head. The total length of the control section is then 24 + 7.2 + 18 or 49.2 inches. Using the above table and the established throat width of 7.15 inches, we obtain a flume of the following shape. The width has been divided by 0.97 to allow for friction loss ahead of the throat.

TABLE 3

Design of Control Section

Distance from Grit Chamber, Ins.	Factor n	Factor m	Width of Section = 7.15 m/.97 Ins.
2.4	0.9	2.18	16.2
4.8	0.8	1.60	11.8
7.2	0.7	1.35	9.9
9.6	0.6	1.22	9.0
12.0	0.5	1.13	8.3
14.4	0.4	1.08	7.9
16.8	0.3	1.04	7.7
19.2	0.2	1.02	7.5
21.6	0.1	1.005	7.4
24.0	0.0	1.0	7.4
27.6	0.0	1.0	7.4
31.2	0.0	1.0	7.4
34.8	0.1	1.005	7.4
38.4	0.2	1.02	7.5
42.0	0.3	1.04	7.7
45.6	0.4	1.08	8.0
49.2	0.5	1.13	8.3

Figure 3 shows the outline of the finished design. It is, of course, not essential that the flume be made with curved sides as shown. This design appears to make for the shortest possible length of control section. If straight sides are used, the approach section ahead of the throat should be longer. It is necessary that the throat be of sufficient length so that the free-flowing condition is well established.

References

1. Camp, U. S. Patent.
2. Holmes Water Works & Sewerage, May, 1933.
3. Barker, Water Works & Sewerage, April, 1939.

Financing Sewage Works Operation

(*Continued from page* 165)

imposed, little more than pays for the extra labor involved. The actual operation of billing takes nearly twice as long as it did for water alone for there are more motions to perform. However, since all other functions involve no extra time, there is no question of a great saving of time, labor and accounting outfits.

Posting

As payment is received, the stub showing both water and sewer payments, penalties if any, is kept, and again sparate totals are taken. The audit sheet, Fig. 6, from the machine once more, must tally and the operation is complete. Posting is done directly from stubs, and totals only are entered in cash book. Miscellaneous charges are handled in a separate ledger and are entered as individual items on cash book when payment is received.

Entries for total billing for each month are taken from audit sheets, as are consumption records. Penalties are noted on stubs when received and posted on ledger sheets together with regular charges. Entries for total receipts are taken from audit sheets as was the billing.

Justification for Procedure

After eighteen months of operation, the writer feels that the ends sought have been accomplished. Considering cost of operation and amortization of indebtedness, rates and minimum billing (48 cents per family unit per month) are low and water use has not decreased on this account. It is a most equitable method, reaching all who should pay for such service, even those who maintain their own water supply. The records set up will be valuable in the future in a variety of ways and once set up, the system is not in the least complicated.

In this eighteen month period under this system with about 3,800 accounts, there has been no desire to make any changes. The method is not troublesome, is accurate and most economical. The same force that formerly handled water accounts alone is now doing both with little more effort. While all this is on a small scale, there is nothing to hinder its application on an expanded scale for a larger city. Perhaps it would then be better to adopt a quarterly instead of a monthly billing period.

WATER WASTE DETECTION BY OBSERVING SEWER FLOWS

By D. D. GROSS, Chief Engineer
Board of Water Commissioners
Denver, Colorado

COLORADO'S pioneers came looking for gold, but stayed to learn that when the welfare of man is considered, water is more valuable even than the glittering nuggets which spelled wealth to the fortunate.

The gold-rush with the famous slogan "Pike's Peak or Bust," resulting in the founding of Denver and the settlement of Colorado, started in 1858. As Colorado grew the demand for water grew and as the demand for water grew the laws governing the use of water grew. The water laws provide that "the first in use is the first in right" to water flowing in Colorado streams. As the requirements of water for irrigation developed faster than the requirement of water for municipal purposes, Denver found it necessary to buy rights to *the use of water,* which implied its return to the streams.

The Importance of Returned Water—Sewage

There seemed to be a policy on the part of irrigation interests to institute litigation to prevent Denver from obtaining more of the direct river flow. It became very important therefore that Denver have available complete and accurate information as to the per cent of water that was returned to the river through the sewers, as well as a record of that taken into the water supply system.

In Colorado we do not consider it good form to talk about the *consumption* of water; it is better to say the *use* of water, fostering the thought that after use much of it is returned to the river. So, we must consider two kinds of water—"new" and "used."

To get at the facts as to the per cent of water used in Denver that was returned to the river we began in 1926 the keeping of records showing the flow of water through the sewers. Charts are prepared on which are shown the use of water in the city. That is the flow of water as metered in the supply conduits, and this flow corrected for loss or gain in the city distribution reservoirs. On the same charts are plotted the amount of flows in the sanitary sewers. This information is computed and plotted for two-hour periods throughout the 24 hours of the day and continually throughout the year.

What Was Learned from the Records

By a study of the charts, such as that here reproduced, over a long period of time we learned that when water was not being used for lawn sprinkling or similar use not capable of return through the sewers, that 95% of the water used was being returned through the sewers. We take this as evidence that there was very little loss of water through leakage in the city pipe system as the ratio of "used" water to "new" water remained fairly constant as the use of water increased or decreased.

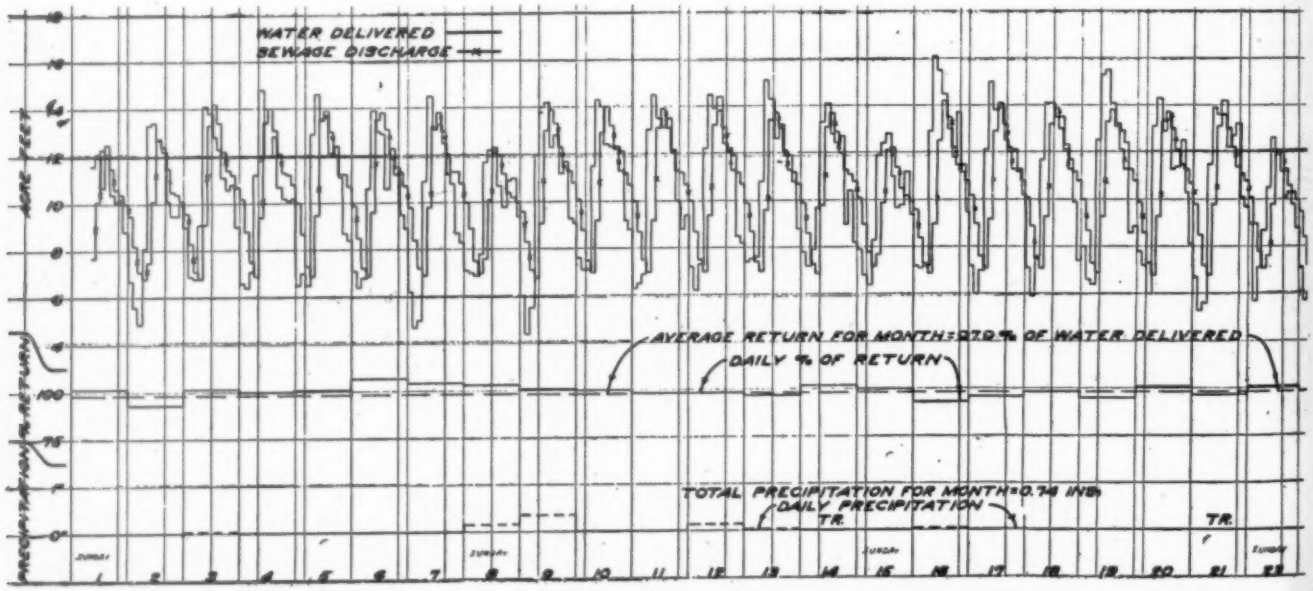
Our experience over a period of years convinces us that both the sewers and water mains are tight, with very little infiltration (say 10%) of ground water into the sewers and very little leakage from the city water mains. When leaks develop in the mains or services the water usually comes to the surface and is detected. However such is frequently not the case and leaks enter somewhere.

A few years ago when we had a cycle of dry years, necessitating a publicity campaign asking the people to conserve water and avoid waste, there was a noticeable reduction in the flow in the sewers. The same condition is observed when an extensive campaign of house-to-house inspection of plumbing is made.

Possibilities of the Scheme and a Plan

At the suggestion of Mr. L. H. Enslow, Editor of WATER WORKS AND SEWERAGE, we decided to make still further use of our sewer gaugings to determine or detect the improper use of water (water theft) in addition to tracing possible hidden leakage of moment.

Under this plan men are sent to inspect sewer manholes for unusual flow of water. We have constantly on duty men we term "servicemen." They are provided with pick-up trucks equipped with radio, maps and tools. It is their duty to respond to all important fires, operate valves, locate leaks, post red lights, etc. At headquarters we have a foreman and two or more men always on duty. If all the men are away from headquarters it is possible for the foreman to get in touch with any one of them at any time as the police department broadcasts our messages. When not otherwise engaged the servicemen do this work. They inspect the manholes at the points where the smallest laterals discharge into the branch sewers. Most of these laterals are from one to three blocks long. No attempt is made to measure the flow. The serviceman observes the amount and makes a notation as "low," "medium" or "high," to designate the amount of flow as compared to the flow in other laterals. These notes are compared when the inspection is repeated. The best time to make inspections for water wastes has been found to be between 2:00 a. m. and 4:00 a. m. At that time the regular flow is at a minimum and any unusual flow is more readily detected. If an unusual flow is discovered at night, an order is given the day servicemen the next morning to make house-to-house inspections and find where the water is coming from.



A Portion of the Water Supply and Sewage Discharge Record for January, 1939

(Note that sewage flows lag behind water use rates by roughly two hours. Note also that sewage flow for month averages almost 98% of water supplied distribution system in a month of negligible infiltration expectancy.)

REX TRAVELING WATER INTAKE SCREENS—assure high capacity and clean water. Their rugged, conservative design gives long life with a minimum of maintenance.

REX SLO-MIXERS—insure low-cost efficient use of chemicals. Paddles operate parallel to flow; turbulence is progressively decreased to promote and maintain optimum flocculation.

What is the vital factor

IN CHOOSING WATER TREATMENT EQUIPMENT?

To most engineers, experience . . . in design, manufacture and application . . . is the most vital factor. That fact explains why so many consulting engineers rely on Rex . . . why Rex equipment is the choice for so many water treatment plants, large and small. Rex equipment is designed by practical men . . . trained in the field and familiar with the problems that confront the water treatment engineer.

For a new plant or the modernizing of an existing plant, Rex engineers can help you select the proper equipment. Rex Intake Screens, Flash-Mixers, Slo-Mixers and Sludge Removal equipment are modern, highly efficient units that are economical in first and operating costs. Rex UNI-FLO, and other conveying and elevating equipment, will handle chemicals efficiently and economically.

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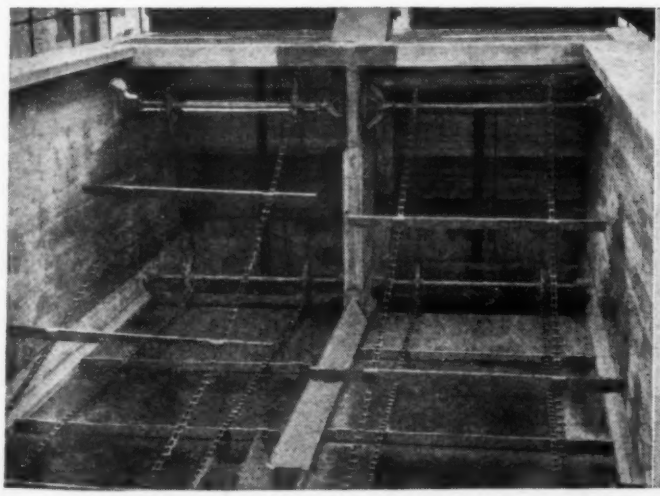
Write for engineering information and descriptive booklets to Chain Belt Company, 1610 West Bruce St., Milwaukee 4, Wisconsin.



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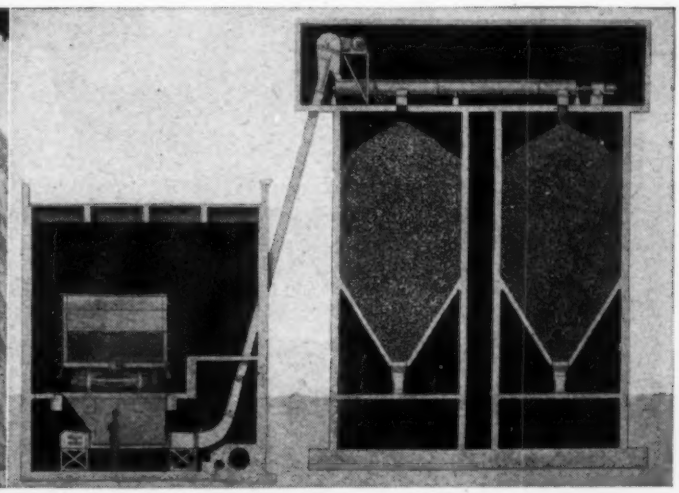

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WATER TREATMENT EQUIPMENT

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GRAVER SEWAGE EQUIPMENT

Aerators — Agitators — Automatic Dosing Siphons — Chemical Feeders — Chemical Proportioners — Chemical Treatment Plants — Coagulators — Clarifiers, Primary and Secondary — Digesters — Grease Removal Equipment — Gas Holders — Imhoff Combination Clarifiers — Reactivator Clarifiers — Rotary Distributors — Skimmers — Sludge Conditioners — Sludge Dryers — Sludge Filters

GRAVER ROTARY DISTRIBUTORS

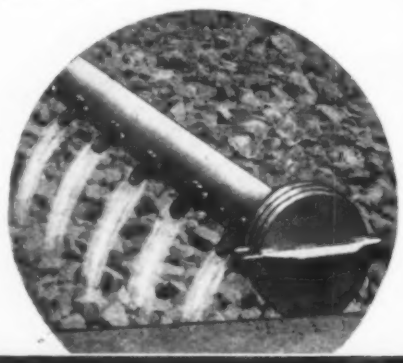
Graver Rotary Distributors are built for all applications of high and low rate trickling filters. The sewage is uniformly sprayed over the rock bed, and the reaction of the discharge propels the mechanism. The center columns are made with either mercury seals, having automatic mercury return in case of blow-outs, or with mechanical seals. The trickling filter effluent may be recirculated if necessary.

Graver Standard Rotary Distributors operate either from an automatic dosing siphon or from a pump. Proper discharge is obtained under a head as low as 6″ at the distributor center column. On the other hand, the head may rise as high as may be required by existing conditions, and the discharge through the distributor arms is still perfectly regular.

Nozzles provide wide, thin spray for proper distribution and aeration. The spray width is adjustable and the nozzles are designed to be fully accessible for ease in cleaning without losing their adjustment.

GRAVER DIGESTER EQUIPMENT

Graver offers a complete line of digester mechanisms and covers which have proven their value in more than ten years of operation. Graver Floating Digester Covers are floated by the gases accumulating under the dome. Agitators can be installed to disperse and submerge scum and promote seeding and inoculation of fresh sludge. Safety features include flame traps and pressure and vacuum relief valves. The equipment is designed so that it is impossible to generate an explosive mixture of gases.



Right—Close-up of Graver Distributor Nozzles.

Below — Installation of Graver Digester Equipment.

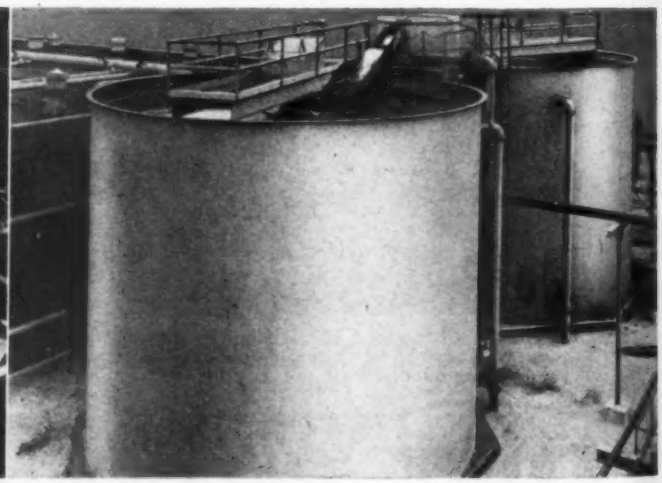
GRAVER REACTIVATOR CLARIFIERS

This equipment is designed to provide high turbidity removal and is ideal for use in primary sewage plants to provide primary treatment or to bring existing overloaded plants back to capacity. With this system, chemicals are mixed with raw sewage, precipitated sludge is recirculated, and the mixture is passed through a suspended sludge bed, insuring intimate contact and complete sludge filtration. Integral aeration is provided to prevent septic action and all steps are carried out in a single tank.

Graver also manufactures a complete line of Primary and Secondary Clarifiers for quiescent clarification in circular settling tanks of small and large diameters. Noteworthy among these is the Graver "Flexidrive" Clarifier which includes such special features as Automatic Scum Trap and Trackless Drive Bridge.

Gravr engineers will gladly discuss your sewage treatment problems with you and cooperate with your engineers in the design of equipment to meet your requirements.

Above—Graver Rotary Distributor installation.



Below—Graver Reactivator Clarifiers.

See Our Advertisement on Water Conditioning Equipment, Page R-145

SEWAGE TREATMENT PROCESSES AND RESULTS

By GEORGE E. SYMONS
Assoc. Editor, Water Works and Sewerage

BY DEFINITION there are only three processes of sewage treatment: primary treatment, secondary treatment, and disinfection. A fourth important part of any sewage treatment operation is the by-product process, solids disposal. Sewage treatment as the name implies is the treatment of liquid wastes to remove or eliminate matter which causes nuisance, and to eliminate or destroy disease producing organisms. All methods of treatment commonly called processes fall into these three basic processes of sewage disposal and their by-product process of solids disposal. Discharge of sewage into large bodies of water is sewage disposal by dilution, without treatment.

Sewage Treatment Processes

Fundamentally, sanitation or sewage treatment is for the purpose of protecting public health and preventing any and all nuisance conditions in a receiving body of water. All receiving bodies of water have a certain inherent capacity for carrying on sewage treatment processes within themselves and disposal by dilution depends entirely on that capacity. When such capacity is overtaxed, the construction of sewage treatment plants is necessitated.

The choice of the processes and methods of carrying them out is dependent on the extent to which this natural capacity is to be utilized. Any decision on the matter must include consideration of the uses to which that receiving body of water is put: water supply, fish culture, pleasure ground, commercial transport route, etc. From these considerations come not only the choice of the basic treatment processes to be used, primary, secondary or disinfection, but also the methods by which they will be carried out.

Primary treatment is the removal of solid particles by physical and mechanical means. Screening, grit removal, grease removal, and sedimentation are included in this process. Important adjuncts or aids to primary treatment or methods of improving the efficiency or effectiveness of the process include chemical precipitation, flocculation, removal of finely divided solids by aeration and vacuum flotation and the removal of grease by air, or air and chlorine combined. The slow sand filter is a primary treatment process in that it is a mechanical means of straining out solid particles. It is also a secondary process in that it depends on biological activity for destroying these solids so removed. Sand disk screens are also a method of primary treatment, as are storm water settling tanks.

Secondary treatment is an oxidation process, wet burning, a process of removal of finely divided solids and colloidal matter and the stabilization and oxidation of these solids and the dissolved organic matter by means of air and the activity of living organisms. The trickling filter and the activated sludge process are the fundamental and best known methods for accomplishing secondary treatment. Important adjuncts, aids, or improvements which increase the efficiency of the trickling filter are preaeration, and recirculation of the filter effluent with higher rates of application of the liquid to the filter. Aids or improvements in the activated sludge process are the addition of chemicals (the Guggenheim Process), tapered aeration, the Hayes Process and the Mallory Process.

Disinfection signifies the destruction of pathogenic or disease carrying bacteria; it does not mean the complete killing (sterilization) of all bacteria and lower forms of life in the sewage. Disinfection is generally accomplished by the introduction of chlorine as a solution, or the introduction of a hypochlorite solution. Most modifications of the disinfection process relate to the point of application of the disinfectant, and its possible use to control odors. Where chlorine or chlorinated products are used to control odors, a by-product process is in operation for sewage treatment, *per se*, is not involved.

Solids disposal, as the name implies, included all types of solids removed in the treatment of sewage. Screenings may be buried, burned, or ground and returned to the sewage as organic solids to be removed later as sludge. Grit may be buried or, if relatively free from organic matter, it may be used as fill or as the bottom of sludge drying beds. When high in organic matter it may be burned. Grease may be buried, burned, or possibly under some conditions, recovered.

Suspended matter removed by sedimentation and handled thereafter as a sludge may be barged to sea; dewatered, dried and burned; digested (with or without gas recovery) and dried on open or covered sand drying beds; chemically and mechanically dewatered, dried and burned; or dried and sold as fertilizer. Elutriation of such sludge is for the purpose of aiding in dewatering before drying and burning. Sludge from secondary treatment process methods may be subjected to the same treatment as primary sludge, i.e., digestion, drying, burning or drying for fertilizer purposes. Final disposition of solids, not sold or used as fertilizer, is as fill, usually near the plant site.

With this brief outline of sewage treatment process and the methods available in each, it is possible to examine the choice of these methods from a design standpoint, as dictated by the extent to which sewage treatment must be carried out. Often a factor to be considered in the choice of the process or of methods used may be the size available for the plant site. Still another factor besides the extent of treatment desired is the cost of installation versus the cost of operation.

Primary Sewage Treatment Process

In the matter of screenings and grit removal the design will probably depend on the preference of the consulting engineer, or on the bid price for the equipment needed. Whether the screenings are ground sub-aqueously or out of water is not finally determinable by data on the effectiveness of the two methods. Whether screenings will be hand or mechanically raked will depend on the size of plant and money available for construction.

Grit chambers are usually designed on the basis of the fundamental concept of differential sedimentation. That is, the design is related to the velocity necessary to keep organic particles in suspension while allowing inert particles to settle. Here the design is dependent on Stokes' law of sedimentation and the relation of specific gravity to velocity. Modifications in design are usually concerned with distribution of flow and control of velocity, and with methods of collecting and removing the settled grit. Washing of the grit will depend on the need for removing putrescible matter before the grit is disposed of. In general, washers of various design accomplish the desired results. Generally, too, such grit washers fail to remove garbage particles which are prevalent in grit from the larger communities.

In the removal of suspended matter by sedimentation there are several factors which affect the efficiency of the process besides the method employed for such removal. These factors include the concentration of the suspended matter (p.p.m.), the detention period (strictly speaking the flow through period), the distribution of flow (i.e., extent of short circuiting), the extent of comminution (dispersion) of the solid particles in the sewage, and, to a lesser degree, theoretically, the temperature of the liquid.

Whether circular tanks or longitudinal tanks should be used is a debatable question. Likewise the type of sludge collecting mechanism used is not of particular importance in the actual operation of the sedimentation process. Arguments concerning the preference of circular over longitudinal tanks usually revolve around the matter of distribution of flow. All efforts to improve the flow characteristics in either type of tank are to prevent short circuiting and to make the actual flow-through time approach the detention time, i.e., the theoretical time that any small portion of the sewage takes to pass through the tanks.

It is well known that changing the baffles in longitudinal and circular tanks will often improve the efficiency of sedimentation and consequently the removal of solids. Aside from such considerations the efficacy of various methods of primary sedimentation may be considered. Plain sedimentation for a period of one to two hours may be generally expected to remove from 30 to 50 per cent of the suspended matter present in the raw sewage and at the same time remove 20 to 30 per cent of the 5-day B.O.D. In highly efficient tanks with detention times of 2 to 3 hours, where the suspended matter reaches the treatment works with very little dispersion or subdivision of particles, the removal of the raw sewage suspended solids may reach 60 to 70 per cent.

Aids to Primary Sedimentation

As an aid to primary sedimentation, flocculation or the building up of particle size by slowly mixing the sewage before sedimentation, may increase the removal of suspended matter from 40 per cent to 60 per cent. A recent primary treatment method under development is the treatment of sewage with air followed by the application of a low vacuum which caused the fine air bubbles

to rise, carrying up small particles of suspended matter and grease. This method claims a removal of approximately 10 to 15 per cent more suspended matter than plain sedimentation. Grease removal with air, or air and chlorine, depends on the quality and amount of grease present and its characteristics as well as the design of the device and the amounts of air and chlorine added.

Slow sand filters will remove 90 per cent or more of suspended matter from raw sewage. Sand disk filters, in reality Reinsch-Wurl screens, covered with sand or crushed coal remove approximately 20 per cent of the suspended matter at best and less than 10 per cent when no filtering medium is used. Electrodialysis as an aid to flocculation gives results of 80 per cent removal of suspended solids and 70 per cent removal of B.O.D. in laboratory experiments.

Chemical precipitation with either aluminum salts or iron salts and lime will aid in the removal of suspended matter and the extent of the removal will depend largely on the amounts of chemicals used. By using large quantities of chemicals it is possible to remove 90 per cent of the suspended matter and 80 to 85 per cent of the 5-day B.O.D. Cost of such treatment is generally quite high and may be prohibitive unless the plant site is so small as to demand the installation of a highly effective method utilizing a small area. In general such quantities of chemicals are not used, and the extent of removal of solids is about 60 per cent with the B.O.D. removal about 50 per cent or better. By means of chemical treatment it is often possible to increase the effectiveness of the primary process thereby decreasing the load on the secondary process. Thus the need for further additions to plant capacity in the secondary treatment process may be eliminated.

Bases of Comparing Primary Sedimentation Results

Whereas the above comparative results have been given in terms of suspended solid removals, it should be remarked that this method of rating the efficiency of sedimentation processes is misleading and improper, if not antiquated. A much better and more applicable method of rating sedimentation processes is to compare the efficiencies as to removal of settleable solids. Obviously, as indicated above, the amount of suspended matter removed will depend on the concentration of suspendid solids and the particle size and density. Some solids should not be expected to settle under any conditions of time and space. Therefore the obvious comparative basis is the efficiency of removal of settleable solids. This efficiency is ascertainable only from the determination of the *settleable* solids.

Although this test is now used at a number of plants throughout the country, it has not been included in previous editions of Standard Methods for Sewage Analysis and only recently has a standard technique been proposed. Without information from this test available, it is impossible to make comparisons of different methods of primary treatment on this basis, but it is believed that flocculation as an aid to primary sedimentation will increase the removal of settleable suspended solids by 10 to 20 per cent, and effective chemical precipitation will, of course, extend this removal. Aeration and vacuation as recently proposed is apparently as effective as plain flocculation in the removal of suspended matter and also seems to offer additional advantages.

Secondary Treatment Process

In the matter of secondary treatment it is quite generally accepted that trickling filters and activated sludge can be designed to produce approximately the same results. The area of plant for trickling filters is much larger than for activated sludge but operation costs for the latter are quite an item considering the air required, whereas in the case of trickling filters there is relatively no cost of operation. Possibly the activated sludge method of secondary treatment will give slightly higher removals of B.O.D. but the method is more susceptible to shock than the trickling filter and may offer several other problems in control.

The high rate filters depend on higher application rates of sewage to trickling filter, and recirculation. This system makes use of the fact that the living organisms on the rock can assimilate and oxidize greater amounts of organic matter if the air is sufficient and the concentration of the organic matter not too high. Recirculation of the effluent of the high rate filter either to the filter itself or to the primary tank influent not only dilutes the concentration of the applied sewage but also brings the organic matter that has passed through the filter in contact with the organisms again. The capacity of the trickling is thus stepped up to four to five times that of the ordinary filter. Conversely it may be stated that the size of filter required is reduced to one-fourth to one-fifth of the ordinary trickling filter. Installations of these types of filters in army camps have proved to be quite effective with reductions of B.O.D. from approximately 400 p.p.m. to 40 p.p.m. Instances are reported wherein the B.O.D. is lowered to the vicinity of 10 p.p.m. The choice of particular method of application of sewage to these filters, the number of filter units in series, and the method of recirculation is one of individual preference and the difference in obtainable results is not within the scope of this general discussion. It must be borne in mind, however, that the high rate or capacity filter costs more to operate than does the standard rate filter.

Aids to Activated Sludge Treatment

Activated sludge processes may be improved by the introduction of the air at different rates to the different sections of the aeration tanks. This is known as tapered aeration and consists of adding about 50 per cent of the total air to the first third of the aeration process, thirty-five per cent of the air to the next third, and the remainder of the air to the last third of the aeration tanks. Increased capacity and increased ability to withstand shock are claimed for this system of aeration. A variation to the tapered air scheme is that of distributed input of settled sewage to the aeration units—notably the New York City practice.

The planned addition of an iron salt to the aeration process constitutes the Guggenheim process. It is generally recognized that where industry contributes moderate quantities of iron-bearing wastes to the sewer system superior results are realized and a more stable system is observed. This condition antedated the Guggenheim patents by a number of years, of course.

The Mallory, or "Oxidized Sludge Process" for secondary treatment is likewise an aeration and sedimentation process ,with the control of the relation of aeration time to sedimenattion time as the outstanding feature. The process seems to serve well under heavy loadings such as milk wastes from which B.O.D. removals as high as 99 per cent have been claimed.

The Hayes process for secondary treatment involves contact aeration in two stages. It has been successful in small installations in the Southwest but has not proved adequate in several army camp installations where the load has been high. Paddle-wheel and other mechanical aerators are mere variations of the activated sludge process. In general they have not been widely installed in this country.

As a decided aid to the activated sludge process one must look back to the development at one of the Ohio plants—that of Lima. Here the method of correcting or preventing sludge bulking by mild chlorination of the recirculated (returned) sludge was first instituted. The practice has spread and New York City, among others, makes effective use of the Lima method.

Disinfection

The extent to which disinfection is practiced is dependent principally on the use of the receiving body of water as a subsequent water supply. If the dilution is relatively small, disinfection may have to be carried to greater extent than if dilution and distance to the next water supply are great. In any event the amount of chlorine required will depend not on the number of original bacteria in the sewage or the number desired in the effluent but on the chlorine demand of the sewage. Not until the chlorine demand (amount of chlorine used up in chemical combination with substances in the sewage) is at least partially satisfied will the bacteria be killed to any extent.

The actual kill depends on the amount of chlorine added, the amount of excess or residual produced, the type of chlorinated compounds formed in the sewage when the chlorine is added, and, most important, the time allowed for the chlorine and chlorinated compounds to act on the bacterial protoplasm. All of the bacteria are not killed, some may be revived on dilution or regrowth may occur from those left, but where the dilution is large and the normal enemies of bacteria in the receiving water sufficient, regrowth is generally not great.

In determining the efficiency of the disinfection treatment it is incorrect and misleading to report results in per cent kill based on the original number of bacteria present. This is obvious from the simple arithmetical relation that 99 per cent kill of 500,000 leaves 5,000 bacteria per unit volume whereas 99 per cent kill of 50,000 leaves only 500 bacteria in the disinfected effluent. For consistent comparisons of disinfection in winter and summer months the results should be reported in the number of unkilled bacteria after disinfection. Where the dilution is large, concentrations of coliform bacteria in the effluent may be as high as 1,000 per ml. without creating an undue load on a water filter plant below.

When dilutions are small disinfection should be carried to a greater extent. In this connection it should be remembered that

(*Continued on page* 180)

For – SEWAGE TREATMENT and WATER PURIFICATION

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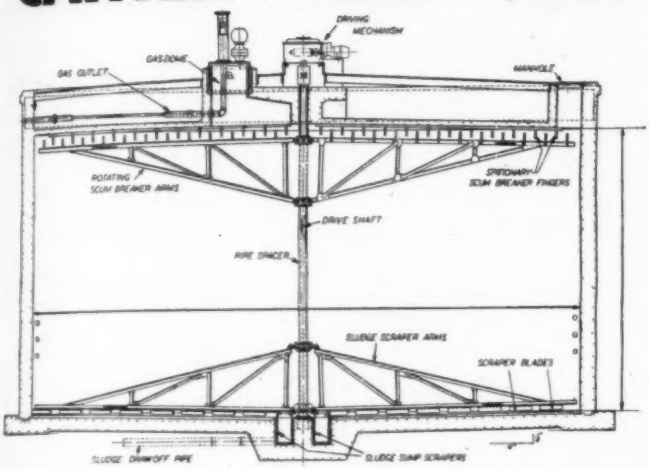
Further detailed information is given in our Bulletins, available on request (see Bulletin numbers at end of each section). Consult us freely, without obligation, on any mechanical equipment problem for Sewage Treatment or Water Purification.

CARTER *FIXED ROOF SLUDGE DIGESTER*



Sectional Elevation
CARTER DIGESTER MECHANISM

RUGGEDLY CONSTRUCTED. Will produce a thickened sludge of uniform consistency and low moisture content. Slow, positive stirring action:

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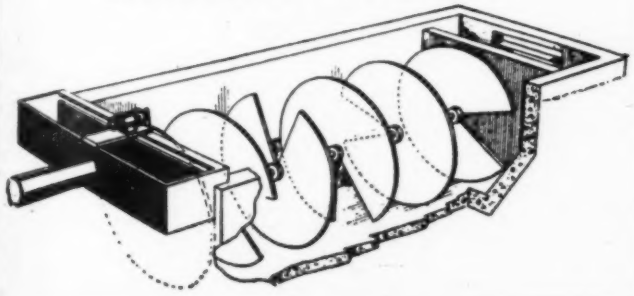

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SLUDGE CONDITIONING for effective Digestion is materially assisted by effective mixing. Varying local conditions of space and elevation call for wide design variations. Carter engineers with many outstanding installations as testimony to their ability, will gladly assist in planning such equipment to meet your most exacting requirements.

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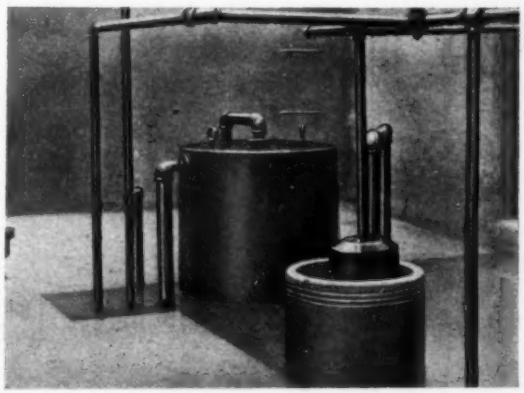

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For Additional Carter Equipment See Page R-131

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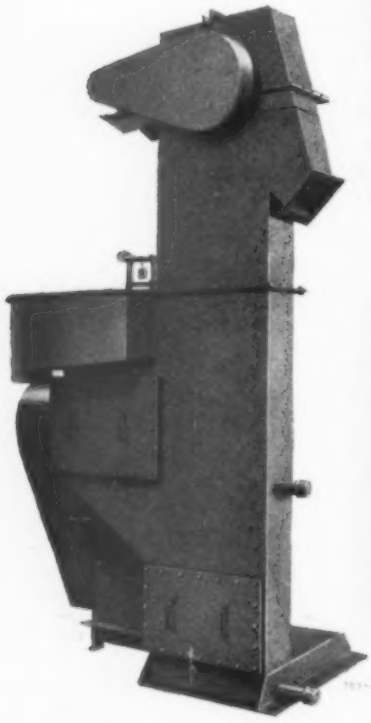
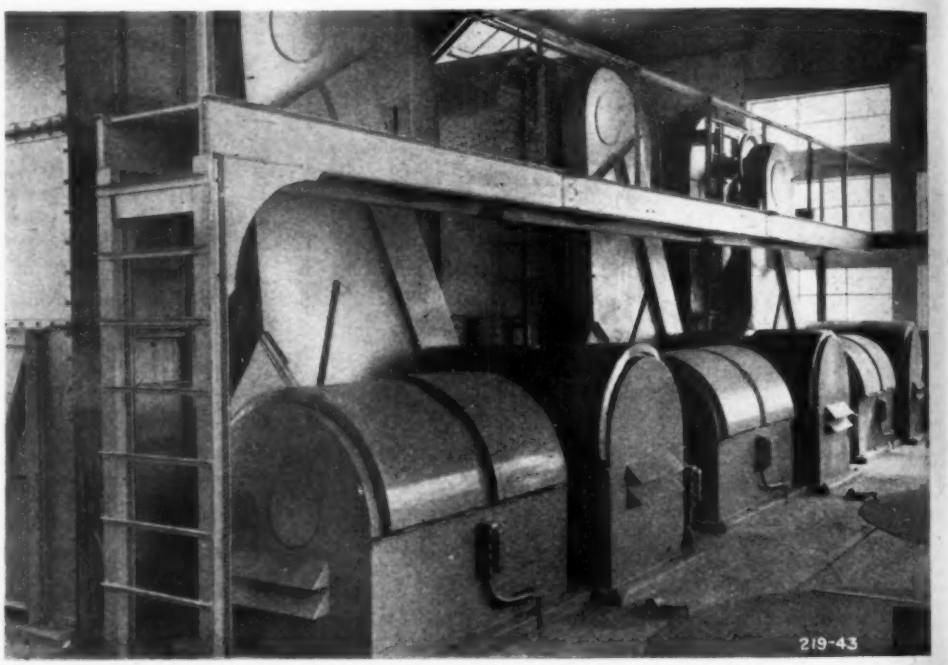
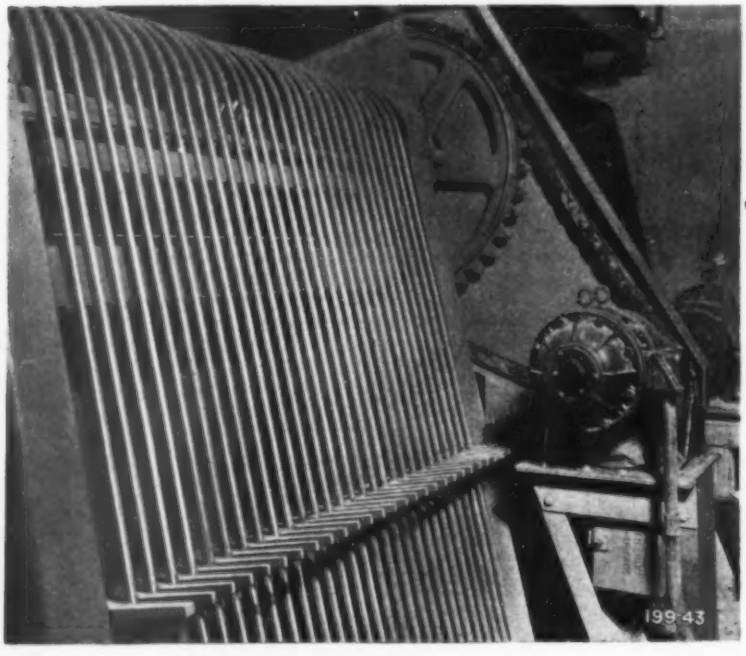
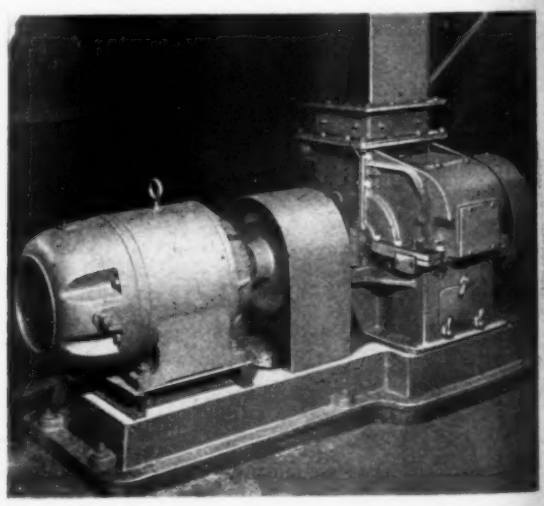


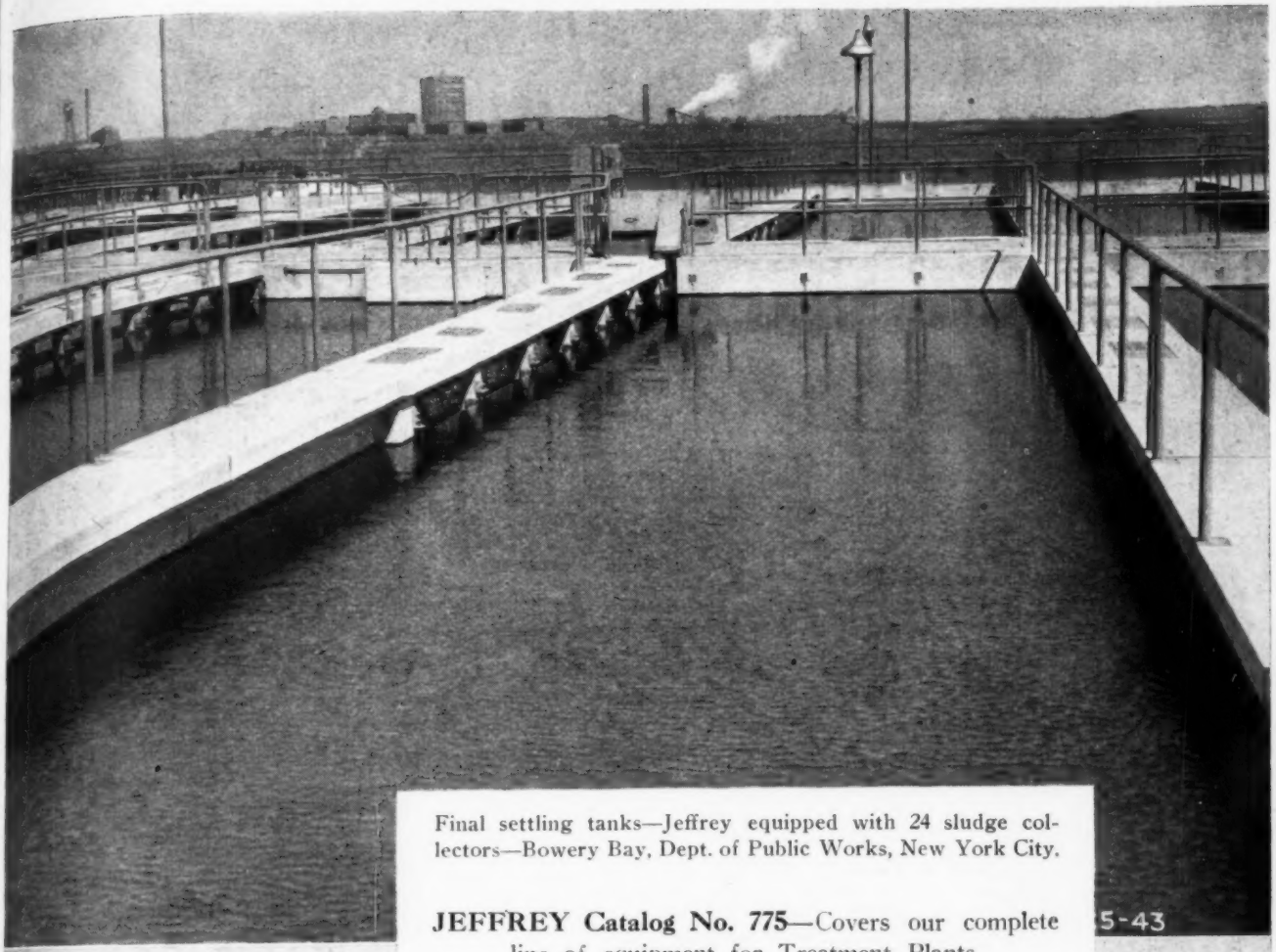


Jeffrey No. 4 Jigrit Washer of latest streamlined design (left). Full automatic control and simplified mechanical details. Jeffrey V-bucket Grit Elevators (above), Bowery Bay Sewage Treatment Works.





Above—Jeffrey Screenings Grinder direct connected to motor. See opposite page for views of Jeffrey-equipped Treatment plants.
Left—New-type Jeffrey mechanically cleaned Screen (cleaning rakes approach from the back).



Final settling tanks—Jeffrey equipped with 24 sludge collectors—Bowery Bay, Dept. of Public Works, New York City.

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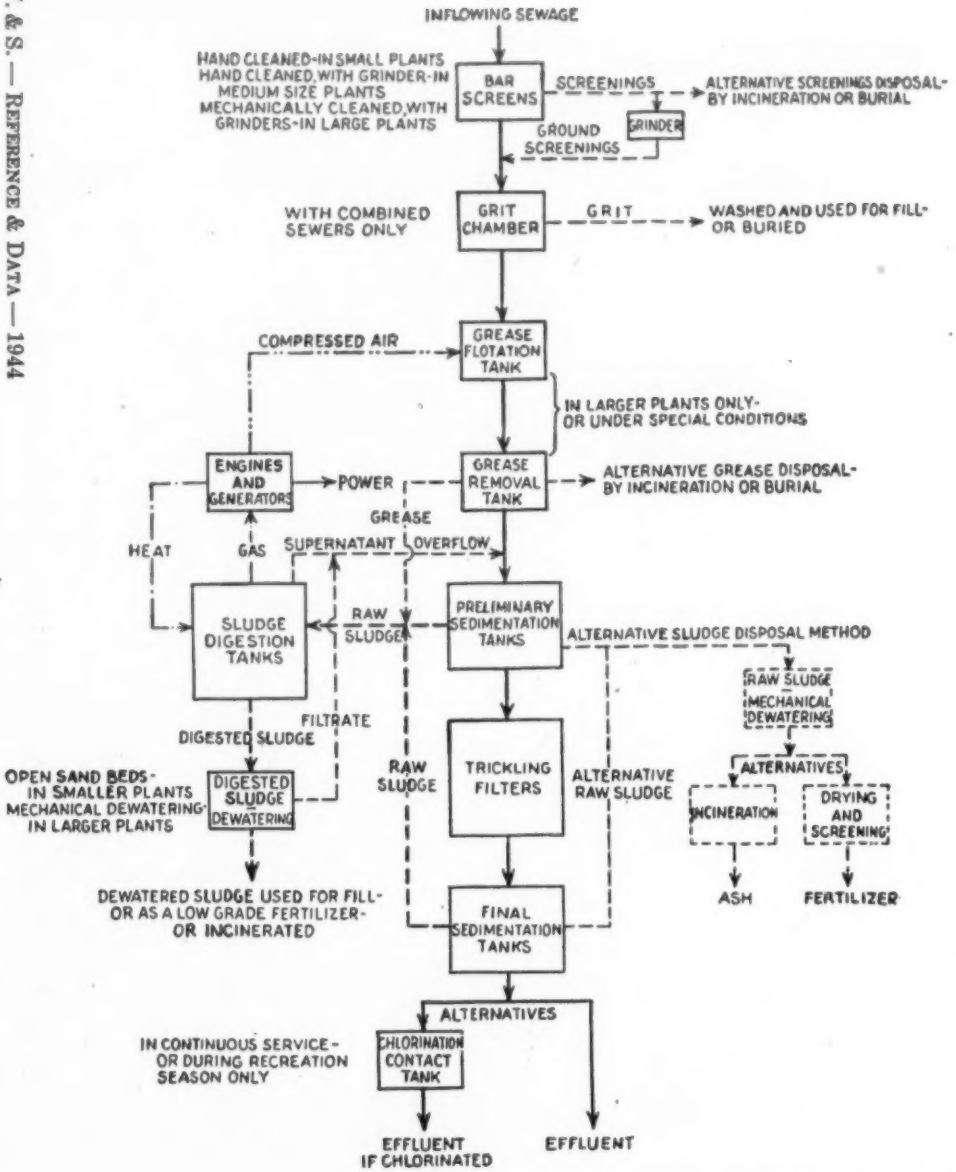
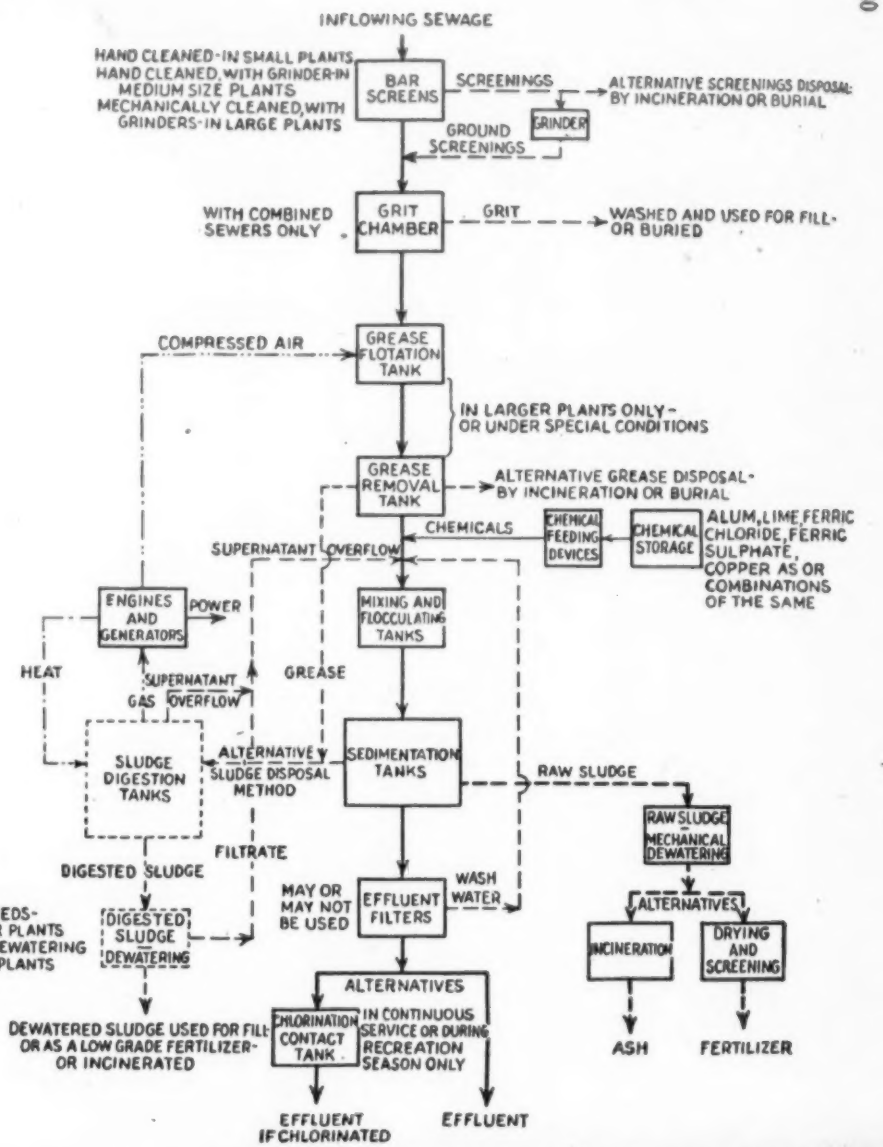
Two final settling tanks—Jeffrey equipped—following high rate trickling filters—Cheektowago Plant, New York.

(Continued from page 176)



Trickling filter sewage-treatment plant, typical flow diagram



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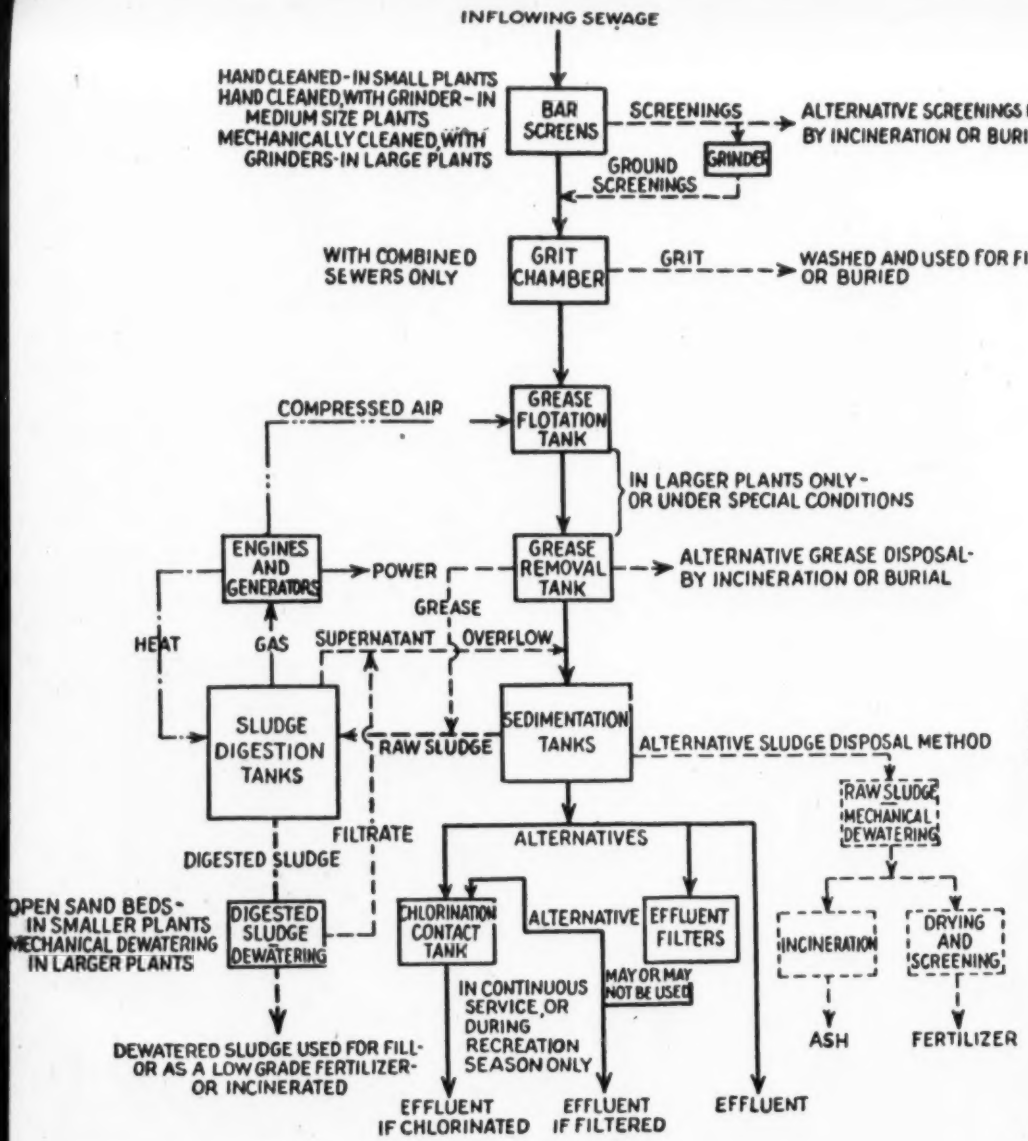
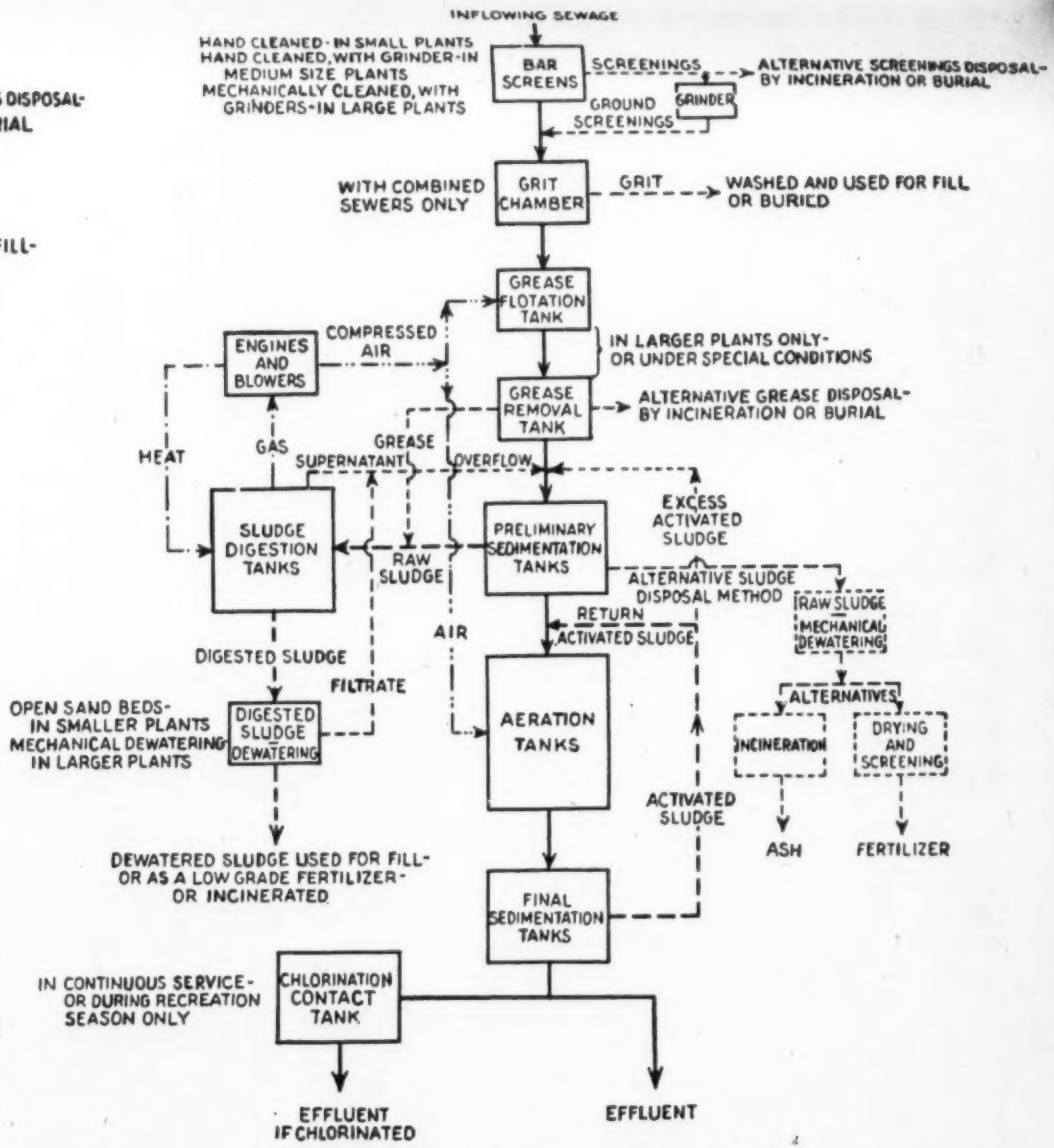
Chemical sewage-treatment plant, typical flow diagram

Trickling filter sewage-treatment plant, typical flow diagram

Chemical sewage-treatment plant, typical flow diagram



Plain sedimentation sewage-treatment plant, typical flow diagram



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Activated sludge sewage-treatment plant, typical flow diagram

(*Continued on page* 184)

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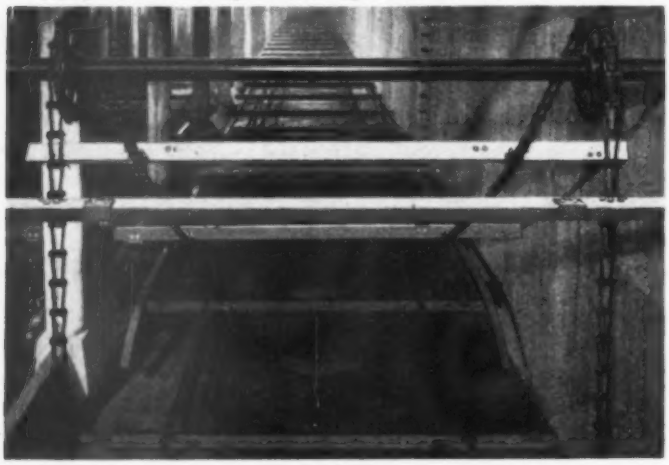
STRAIGHTLINE COLLECTORS

Link-Belt STRAIGHTLINE Sludge Collectors for the removal of sludge from rectangular settling tanks consist of two strands



of especially processed malleable chain from which are suspended at uniform intervals scraper flights usually made from red wood. Features are peak-cap bearings, pivoted flights, cross collectors for larger tanks, and positive sludge removal at a slow, uniform speed. Auotmatic or semi-automatic skimming equipment is furnished when required.

Many installations are now in service in all parts of the country and range in size from the smaller type plants as at Tappahannock, Va., with a capacity of 80,000 G.P.D., to larger installations such as Ward's Island, N. Y., with a capacity of 180,000,000 G.P.D., and Southwest Plant, Sanitary District of Chicago with a maximum capacity of 600,000,000 G.P.D.

Many features of the Link-Belt STRAIGHTLINE Collector are patented. Send for Book No. 1742.

STRAIGHTLINE MIXERS FOR FLOCCULATION TANKS

Link-Belt STRAIGHTLINE Mixers of the vertical or horizontal type have proved their value in reducing chemical costs and promoting efficient flocculation in water and sewage treatment plants. They consist of a shaft to which is fastened arms which carry either wood or steel paddles that can be pivoted so that the flights can be adjusted to obtain the exact degree of uniform agitation. The maximum circumferencial speed of the mixers for flocculation tanks is 1.8 f.p.s., and the minimum speed is about half of that. A gradual decrease in speed of the units is desirable for efficient flocculation.

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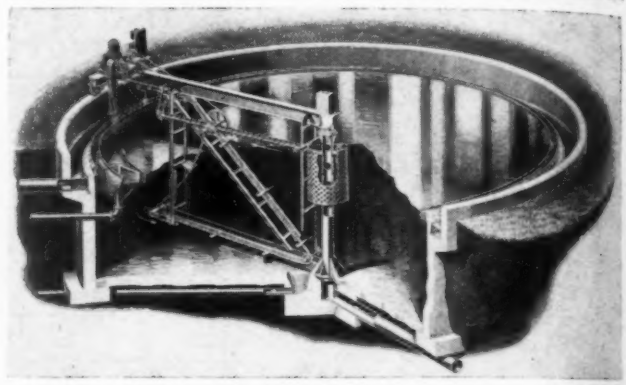

Drawing of Link-Belt Type "B" Circuline Collector.

CIRCULINE COLLECTORS

Link-Belt CIRCULINE Collectors for the removal of sludge from round tanks consist of a flight conveyor suspended from a bridge, one end of which is pivoted at the center and the other end is mounted on standard rubber-tired wheels which travel around at circumference of the tank. Features are: positive, slow, uniform speed; positive sludge removal and excellent distribution of flow throughout the tank; improved, automatic scum collecting screw conveyor and scum receiving hopper as standard equipment. Made in two standard sizes — Type "B" for Tanks up to 55′ dia.; Type "A" for larger sizes up to 200′ dia. Send for Book No. 1982.

Link-Belt Type "A" Circuline sludge collector in 70-ft. diameter final settling tank at an army camp sewage treatment plant.

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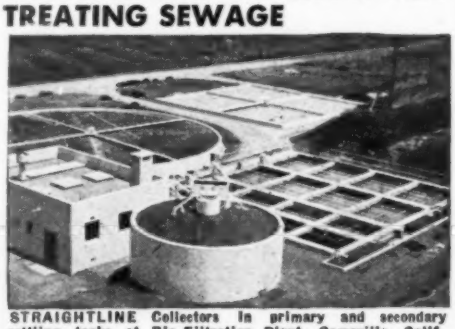
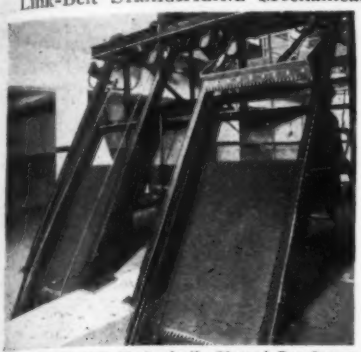


STRAIGHTLINE Collectors in primary and secondary settling tanks at Bio-Filtration Plant, Camarillo, Calif.

Bio-Filtration Sewage Treatment System with Link-Belt STRAIGHTLINE and CIRCULINE Collectors brings new advantages. The system consists of high rate shallow filter beds and recirculation of the effluent from the filter beds to the primary tanks. Features are great flexibility, high rate of B.O.D. loading and the ability of such a plant to handle strong domestic and industrial sewage in single-stage or two-stage treatment, as required. A large number of installations of this type are now in operation. Send for Folder No. 1881.

STRAIGHTLINE BAR SCREENS

Link-Belt STRAIGHTLINE Mechanically Cleaned Bar Screens have spaced parallel bars on which the larger floating solids in incoming sewage collect, and a mechanically operated rake for removal of the accumulating solids, thus assuring an even flow of sewage through the channel. The machine may be set vertically or inclined, and used in small or large plants.

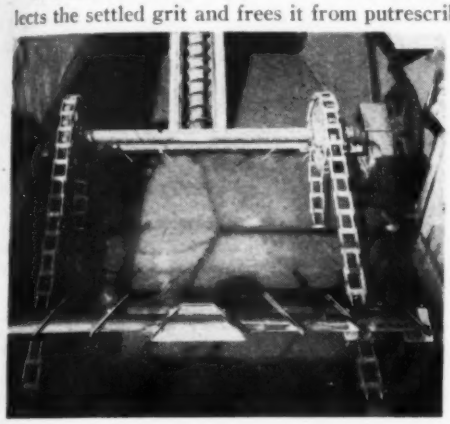


STRAIGHTLINE Mechanically-Cleaned Bar Screen at Sewage Pumping Station, Lackawanna, N. Y.

Send for Booklet No. 1587.

STRAIGHTLINE GRIT COLLECTORS AND WASHERS

The Link-Belt STRAIGHTLINE Grit Collector and Washer collects the settled grit and frees it from putrescribe organic matter. This unit consists of a scraper type collector with pitched flights, and an inclined washing and dewatering screw to which the collector conveys and into which it discharges the grit at bottom of tank. Send for Book No. 1942.



INDUSTRIAL WASTE SCREENS

The Link-Belt Industrial Waste Screen is an efficient and economical unit for the removal of objectionable suspended solids from industrial waste before the water is discharged into sewers or streams. The screenings come off the machine with a minimum of moisture. Units are available in several sizes and with coarse or fine screen medium. Wastes from canneries, textile mills, steel mills, etc., are handled successfully by these screens. Send for Book No. 1977. We also manufacture rotary screens for similar service.

This "Liquid" waste screen separates refuse from water as received from beet pulp washers before discharging to sewage system.

TRITOR SCREENS

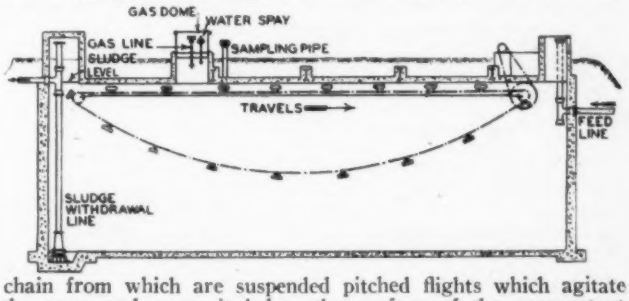
The Link-Belt Tritor Screen is a combination of screen and grit chamber. It is especially designed for medium and small size plants. Its main elements are a hopper, a bar screen, and a bucket elevator for removing grit from hopper, the buckets being perforated for drainage. On return run, rake teeth on buckets clean the screen. Adjustable baffles regulate velocity of flow through the hopper.

Booklet No. 1587.

TRITOR Screen, fully-enclosed type, at Salisbury, N. C. Sewage Plant.

STRAIGHTLINE SCUM BREAKERS

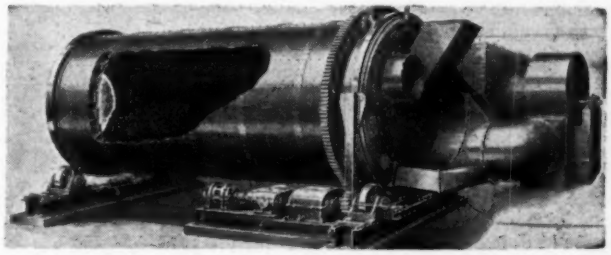
The scum breaker is used in digestion tanks to paddle down and submerge the floating scum. It consists of two strands of



chain from which are suspended pitched flights which agitate the scum and carry it below the surface of the supernatant liquor. Features are rugged construction and automatic take-up where required.

ROTO-LOUVRE HEAT DRYERS

The Link-Belt Roto-Louvre heat dryer consists of a mechanically rotated horizontal drum with a series of internal channels near the circumference into which hot air enters, leaving then through slots to enter the inside of the drum, which contains the



sludge; hot air entering the channels only when they are near the bottom, and thus all passing through the sludge. Due to this intimate contact of drying medium with material, high efficiency is obtained keeping floor space requirements at a minimum. Dry material discharges from dryer at a low temperature of about 150° F and the unit is equipped with automatic controls that maintain the desired discharge moisture content. No cascading takes place, thereby minimizing degradation and wear. Send for Book No. 1911.

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9575

(*Continued from page* 181)

if organic matter, suspended or dissolved, is not removed from sewage, no amount of disinfection will prevent that matter from decomposing at some later time when the bacterial population has been reestablished. Thus the discharge of chlorinated sewage into a small stream affording a low dilution merely moves the point of nuisance farther downstream or otherwise delays the bacterial degradation of the organic matter.

The point of application of the chlorine in sewage treatment may depend on several factors. If the chlorine is added up-sewer it is usually for the purpose of odor prevention, principally by killing the bacteria which will convert sulphates into hydrogen sulfide. Addition of chlorine prior to sedimentation is pre-chlorination and usually prevents odors as well as giving longer contact time for the chlorine to act as a disinfectant. It may, by preventing the formation of hydrogen sulphide in the settling tanks, also reduce the amount of chlorine used. For a normal domestic sewage it probably does not require much more chlorine for pre-chlorination than for post-chlorination.

The length of time required for disinfection (contact time) should be at least 15 minutes with a residual chlorine at the end of that time of possibly 0.5 p.p.m. If further contact time is available after 15 minutes, the residual at 15 minutes may be as low as 0.1 p.p.m., or there may even be a slight chlorine demand at that time. Chlorinated compounds formed in sewage act as bacteriacides if given sufficient time of contact. In large plants, where chlorination is important, it may be economically advantageous to utilize these chlorinated compounds rather than depend on high chlorine residuals for short contact times.

General Considerations

It is apparent from the above observations that each method of treatment has its use and application. Combinations of the processes or even of several methods in a single process may prove to be advantageous for a special problem. Usually each installation of a sewage treatment plant is a separate problem.

Disinfection is rarely practiced alone except where it is desired to eliminate a nuisance in the immediate vicinity of an outfall and allow the sewage to become more diluted before bacterial activity sets in. Primary treatment to remove suspended matter and chlorination are used when it is desired to reduce local nuisance and protect water supplies. This combination usually occurs where the dilution is great.

Primary and secondary treatment are usually combined when it is necessary to eliminate organic and bacterial nuisance completely and, as a further protection for bacterial removal, post-chlorination may be added. Secondary treatment alone is not practical. The choice of the method of carrying out these primary and secondary treatment processes may best be determined by the designing engineer when he decides on the amount of the load that each process should carry. This decision may well rest on the economics involved.

For example, at one installation a very small part of the load may be carried by a settling tank designed to remove only the coarse materials with the rest of the load to be carried by the activated sludge process. Conversely, preaeration of sewage before discharge onto trickling filters may be more economical for another plant. Choice of high rate filters as against standard rate and activated sludge likewise is a matter of economics in many instances.

Solids Disposal

The type or method used in solids disposal is quite generally decided on the basis of the economics involved. Obviously for a small community, vacuum filtration, drying and incineration are not feasible because of the smallness of the equipment required and the personnel necessary to operate such equipment. Sludge digestion and drying on sand beds remains the best method in such locations.

For these installations, without heat for digestion, the sludge may be reduced by about fifty per cent in volume and the solids 25 per cent by weight; with heat the reduction is greater. In larger cities, sludge digestion, mechanical dewatering, drying and incineration appear to offer many advantages particularly if the available land for ultimate disposal by fill is not conveniently located. Whether the sludge is sold or given away as fertilizer, depends primarily on the local market and the fertilizer value of the sludge, which, in turn, may depend on the type of treatment of sewage or the extent of digestion of the sewage solids. Barging of sludge to sea is a matter of locality as well as economics.

Inasmuch as the disposal of solids is but a by-product process of sewage treatment and not sewage treatment itself, comment on the methods of such disposal and results obtained are not primarily a part of this presentation.

Summary

In summary, it is sufficient to say that whether choosing the type of treatment process, the method of carrying it out, or the method of disposing of the important and nuisance giving solids removed, the important considerations in the decision as to choice rests on the realization and understanding of the following basic factors: The use of the receiving body of water, the capacity of the receiving body of water to receive sewage, the size of the plant site, the availability of dumping grounds for the by-product, and the economics involved in adjusting the relation between the various processes and/or the methods used between first cost and operation costs. This is but another way of saying that the choice of sewage treatment processes or methods should depend on the extent of treatment needed or desired and the best results obtainable from various combinations of these methods at the lowest possible cost for installation and for operation.

The accompanying flow diagrams show variations of combinations of methods and equipment used to effect sewage treatment.

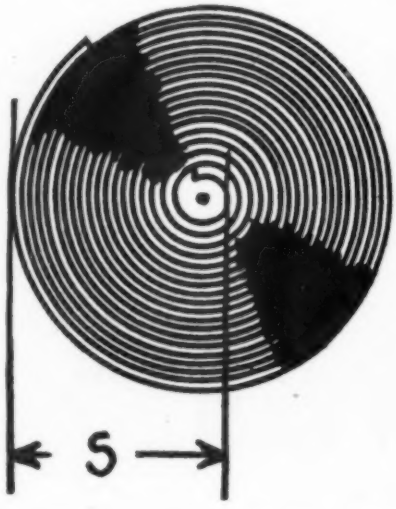
QUICK WAY TO ESTIMATE LENGTH OF MATERIAL IN ANY ROLL OR COIL*

MOST of us are users of considerable material that comes in rolls—paper, hose, belting, cables, wire, etc.—and the question often arises, "How much material remains in that roll?" Or, "Does the original roll contain full length?"

There are numerous formulas for computing lengths in rolls, but I find that all of them are more or less complicated. We are told to find the outside diameter, the inside diameter, then subtract, multiply, and do various other things, and finally we get the answer.

Here is a simple rule of my own derivation which I contend is the simplest possible: Make the one measurement "S," as shown in the sketch herewith, in inches. Then count the number of turns. Multiply the two together and then multiply that by 0.2618. The result is the length of material in feet.

For example, if the distance "S" is 10 inches, and the number of turns is 10, the roll contains 26.18 feet.



This holds true regardless of whether the material is paper, leather, or anything else. The thickness of the material does not make any difference.

To check the rule, take an instance where we have only one single turn of belting, the distance "S" being 10 inches. The roll, then, is a true circle, and the distance "S" is the diameter of that circle. The length of the belt, of course, is equal to the diameter times 3.1416 or, 31.416 inches. Now divide that by 12 inches and you will get 2.618 feet, as per the above rule.

Even if the roll is so tightly wound that there is no visible hole through it, the rule still holds true. And, ditto, if it is loosely wound.

*Contributed by W. F. Schaphorst, M.E.

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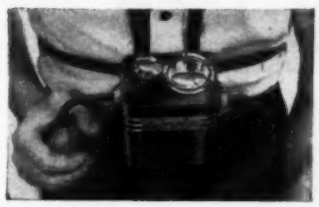

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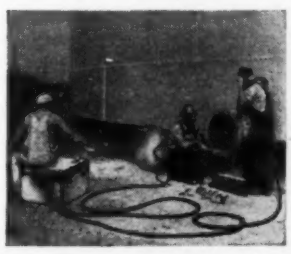

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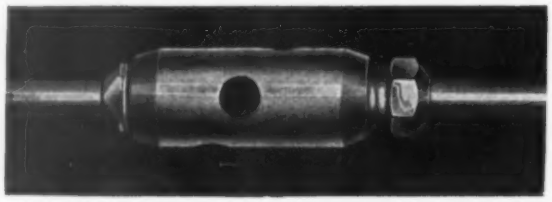

FLEXIBLE couplings are made of ⅞ inch special heat-treated round bars, drilled out 9/16 inch and threaded in each end. Two holes are drilled to receive the "elbow bends" in the rods to be joined by the coupling. Rods are removed by unscrewing the coarse thread end nut. The fine-thread nut is left-handed and is permanently tight. The ⅜ inch crosswise hole permits use of a pin for turning.

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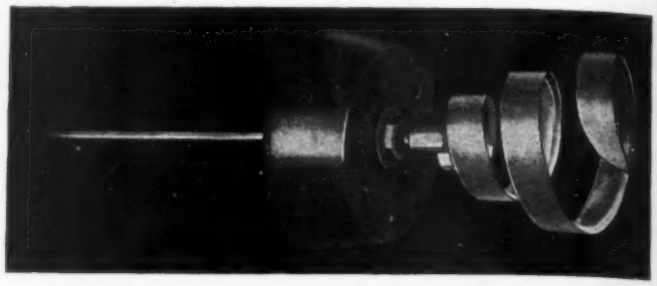

Here is the proper set-up for a sand job. The rubber sand cups are especially compounded to withstand oil, grease, gasoline and sewer acids.

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Has cutting edge front and back. Recommended for removing long, stringy roots, sand, dirt, grease, etc.

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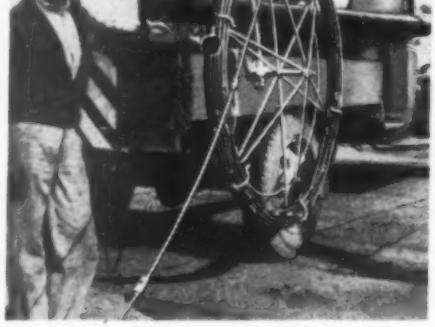

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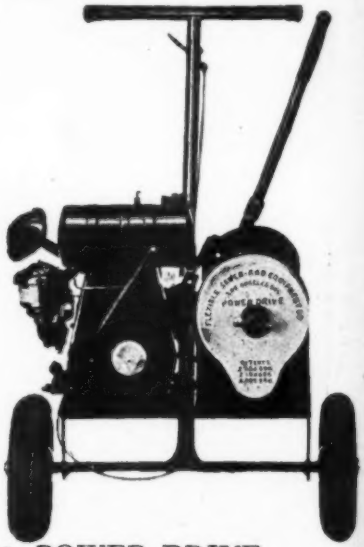

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EXPERIENCE IN SEWER MAINTENANCE*

By W. H. WISELY
Exec. Secy. and Editor, Federation of Sewage Works Assns.

THE practices and experiences presented in this article were contributed by the following, whose cooperation is gratefully acknowledged:

Auburn Sewerage District, Auburn, Me.
Bridges, F. B., Supt. Water and Light, Kahoka, Mo.
Carpenter, G. D., Supt. Water and Sewers, Ithaca, N. Y.
Case, R. G., Supt. of Sewers, Merchantville, N. J.
Castello, W. O., Asst. Engineer, Sacramento, Cal.
Classen, A. G., Supt. of Sewers, El Paso, Tex.
Comte, E. A., Mayor, Murphysboro, Ill.
Corson, H. H., City Engineer, Birmingham, Mich.
Crusinberry, R. R., City Engineer, Cimarron, Kan.
Dance, Mark G., Director of Public Works, Birmingham, Mich.
Eiler, W. L., Supt. Sewers, Cannon Falls, Minn.
Hart, Bert, Supt. of Streets, Rock Falls, Ill.
Hendryx, Orie G., Supt. Bloomington-Normal (Ill.) San. Dist.
Kilpatrick, J. F., City Engineer, Rolla, Mo.
McNeice, L. G., Engineer, Orillia, Ontario.
Morrow, Ben S., City Engineer, Portland, Ore.
Olney, F. J., Supt. Sewers, Proctor, Vt.
Phelps, Byrl D., Asst. City Engineer, San Diego, Cal.
Semmes, O. J., Jr., City Engineer, Pensacola, Fla.
Sperry, W. A., Supt. Sanitary District, Aurora, Ill.
Steelman, E. S., Mgr., Ocean City (N. J.) Sewer Service.

Of all sewage works operation functions, that of sewer maintenance is usually considered the least pleasant and interesting, yet it is of utmost importance. There is somewhat of an inclination to neglect this essential "chore" in many cases even though the hazards of basement flooding and other effects of faulty sewer operation are appreciated. Good will that has been carefully built up by painstaking public relations activity can be easily destroyed in this way.

Maintenance Program—Records and Inspection

The most important item of equipment in any sewer department is a master map of the system, supplemented by larger scale sectional maps on which are shown important details such as direction of flow, exact manhole locations, sewer sizes and slopes, house connections, etc. Phelps (San Diego) has found that good maps save time and minimize damage to streets and private property, and recommends that all extensions to the system be plotted as made so that the reference maps will always be up-to-date. At Rockville Center, N. Y., Anderson[1] keeps a card index for permanent notes and a log book for daily maintenance notes, both of which are indexed to the sectional maps. The log book is kept by the field crew and records the location of work, conditions found, equipment used and daily costs.

Practice as regards frequency of routine inspection varies widely. Several contributors report that inspections are made only as difficulty arises, while others confine routine inspection to those sewers which have given trouble previously. A number of those reporting this inspection practice indicate that lack of personnel obviates a regular schedule.

Most general inspection practice appears to be as follows: sewers on flat grades or previously troubled by roots—every three months; sewers in which no trouble has been recorded—once to twice yearly; main intercepting sewers—one to four times per month; flush tanks—every month; inverted siphons—one to four times monthly; storm water overflows—during and following heavy rains. Some larger cities maintain a trained inspection crew which is continuously engaged in following a prepared schedule.

Anderson[1] warns that a casual glance into the manhole does not constitute adequate inspection. Steelman (Ocean City) advises inspection of critical sections during peak flows, which advice is substantiated by experience at Urbana-Champaign, Ill., where an 18-inch interceptor appeared to be flowing freely during numerous dry weather observations but was found to be carrying only 25 per cent of capacity when surcharged at the upper end during a very wet season, due to an unusually bad root condition. "Lamping" a section, by looking through the sewer during low flows toward a flashlight (explosion proof) held at the next manhole, is a common method of inspecting lines of 12-inch diameter and larger. Superintendent Case (Merchantville-Pennsauken, N. J.) employs an inspection crew of three men who ascertain the condition of the line by observation at the lower manhole while the line is being flushed or probed with light rods. A change in the color or solids content of the flow will indicate an accumulation. At Birmingham, Mich., the condition of lateral sewers is ascertained whenever an opening is made for a new house service connection.

Where a program of routine cleaning "whether they need it or not" is possible, it is usually correlated with the inspection schedule. At Cimarron, Kan., City Engineer R. R. Crusinberry has developed a schedule of routine cleaning that enables coverage of the entire system every year. At Rockville Centre, where there are 78 miles of sewers, Anderson[1] has planned to clean 26 miles of sewer each year, thus covering the entire system every three years. The work is carried out from March 15 to July 1 and from September to November, totalling about 150 days of the most suitable weather. Work in the business district is done between 4 a.m. and noon to avoid heavy traffic. A similar 3-year schedule for cleaning trunk line sewers, involving work on about 33 miles of sewer per year, has been developed by Superintendent George D. Carpenter at Ithaca, N. Y.

Baltimore, Md., has a well organized plan for continuously servicing the 1,900 miles of sewers and drains in that city.[2] Five crews of three men each are assigned to definite territories and are equipped to clean street inlets and manholes, approximately 1,200 to 1,500 being cleaned weekly. Four crews of five men each are equipped for servicing house connections and small laterals and are constantly engaged in this work. One six-man crew is equipped to work on large sewers and drains. The plan affords continuous maintenance, minimizing complaints and inconvenience to property owners.

Twenty-nine well equipped field crews are able to completely cover the 2,800 miles of sewers in Los Angeles, Cal., twice each year by working according to a systematic plan.[3]

Any routine sewer cleaning program must be arranged to allow for interruptions for emergency calls.

Sewer Maintenance Equipment

The size and type of sewers to be serviced, of course, determine largely the nature of equipment required, but certain items are essential to any efficient crew. Sanitary sewers will usually be troubled mostly by roots and grease, while combined or storm sewers will nearly always accumulate grit and are most likely to receive miscellaneous debris. The equipment carried by the maintenance crew will be most adapted to the character of stoppages anticipated but there must also be equipment for handling the unexpected.

A typical list of essential equipment carried by a full-time, large city maintenance crew working on all types of sewers has been developed from data furnished by the contributors to this article:

Major Equipment

- 2½ ton truck
- Power winch
- Portable, manually-operated winch
- 1,000 feet flexible steel cable
- 1,000 feet fire hose
- 600-800 feet flexible rods (power drive desirable)
- 500 feet interlocking wood sewer rods
- Root cutters of assorted sizes
- Sewer brushes of assorted sizes
- Sand buckets, scoops and drags of assorted sizes
- Turbine flushing heads
- Steel sewer tapes and heavy wire (for small sewers)
- Sewer flushing bags

Minor Equipment

- Shovels, picks and mattocks
- Assorted wrenches
- Hydrant and manhole tools
- Flash lights (explosion proof)
- Rubber boots, coats and gloves
- Buckets and rope

Safety Equipment*

- Hydrogen sulfide detector
- Carbon monoxide detector
- Combustible gas indicator
- Wolf safety lamp
- Hose mask (double) with safety harness

*From "The Operator's Corner," Sew. Wks. Jour. 14, 410, 1942. Reprinted by permission of the Federation of Sewage Works Associations.

*A combination combustible gas indicator, oxygen deficiency lamp, and toxic gas detector is available on the market.

Safety belts (2 or 3)
Complete first aid kit
Manhole guard rails
Traffic signs and flags
Oil lamps and flares

Commenting on the above list, the power winch for pulling scoops, brushes or buckets may be provided for in several ways. There are several excellent portable power units (Fig. 1) available, specifically designed for sewer cleaning, in which the engine, cable reel (with control clutch) and pulley frame are mounted on wheels and can be moved about as a trailer. At Champaign, Ill., the winch is mounted on the truck and is powered by the truck motor.

The sewer service crew of the Joint Meeting Sewer Commission of New Jersey is equipped with several unusual items which have proven highly useful.[3] A short-wave radio receiving set keeps the crew in contact with headquarters regardless of their location about the large area in which they must work; a portable platform derrick expedites heavy loading jobs and is used to transport the sewer cleaning winches; a portable, 1,500-watt generator supplies current for floodlights used in night work and for the portable air blower employed in ventilating sewers and manholes as a safety measure. Portable generators are also carried on some of the sewer maintenance trucks used at Los Angeles.[9]

The sewer maintenance departments of cities of moderate and small size are seldom equipped as completely as listed above, despite the fact that the best of equipment yields greatest economy. Commonly, the general purpose city truck is used to transport loose equipment or pull a small trailer. The truck is sometimes used to pull scoops, drags or brushes as a substitute for more suitable power machines. There is also an unfortunate tendency for small city crews to work without adequate safety equipment and fatal accidents in such crews are much too common. Phelps (San Diego) suggests that the cooperation of the local gas company be obtained when special testing equipment is required for occasional gas surveys.

Character of Sewer Stoppages

The most common obstructions in sewers, in the order of greatest incidence, are (1) roots, (2) accumulations of grease, (3) grit and (4) miscellaneous debris.

Roots generally enter at faulty joints. Growth usually occurs from a single leader root which continues developing inside the sewer until branches from the leader often fill the entire pipe. Phelps reports one root growth 30 feet in length (Fig. 4) removed from a sewer in San Diego. An unusual root removed in San Diego is shown in Fig. 5. Care in making joints, use of proper jointing materials and careful tamping of backfill during sewer construction are good insurance against root troubles later.

Copper, toxic to most plants, has been employed to control root growths. A copper ring, made for the purpose, is available for placing in the joint at the time the sewer is laid. Killing of root growths in sewers by copper sulfate is successfully practiced at San Diego, Cal., and Greenville, Tenn., and elsewhere, a handful of blue vitriol crystals being dropped into a manhole above the suspected root growth, while flow is taking place. Repeated applications may be necessary to kill the leader growth, which later break loose due to the water pressure behind it.

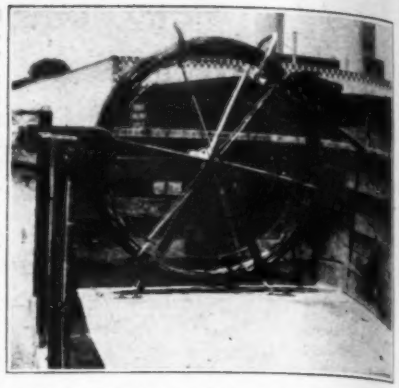

Fig. 2—Method of Using Flexible Sewer Rod Reel in Truck.

Superintendent Case of Merchantville, N. J., reports most root troubles caused by poplar and willow trees and these are removed where difficulty has been caused, to prevent recurrence.

Grease accumulations on the inside of the sewer and in the form of floating balls is a major problem at Atlantic City, N. J.,[4] and other places. Ordinarily discharged to the sewer with hot or warm water, the grease congeals as it cools and adheres to the walls of the sewer or develops into a ball with some small particle or object as a nucleus. These accumulations continue to build up until they materially reduce the capacity of the sewer.

Grit in the form of cinders, ashes, sand, mud, etc., which enters combined and storm sewers with surface water run-off and

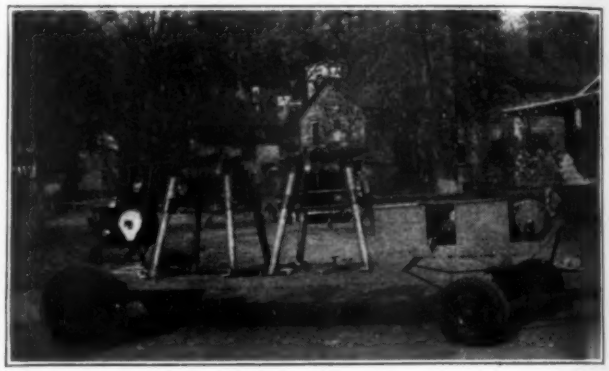

Fig. 3—Power Driven Sewer "Drag" Mounted on Trailer at Ithaca, N. Y.

sanitary sewers with basement drainage, is often troublesome, particularly where sewers are on flat grades. At Rock Falls, Ill., and elsewhere, unpaved streets are the source of excessive grit deposits in sewers. Sewers laid through quicksand often shift due to the unstable foundation, opening at the joints and permitting the fine sand to enter. This condition is serious at East Aurora, N. Y., and, to a lesser extent, at Ocean City, N. J. Mud and sand originating at automobile wash racks is reported to be a cause of grit accumulation in sewers at Kahoka, Mo., and Cimarron, Kan.

The character of miscellaneous debris removed from sewers (combined and storm drains in particular) is almost unimaginable. Barrels, posts and a bed spring are on the list at Bloomington-Normal, Ill., and a washing machine was once removed from a large line at Springfield, Ill. Removal of some of these articles demands much ingenuity and patience on the part of sewer maintenance personnel.

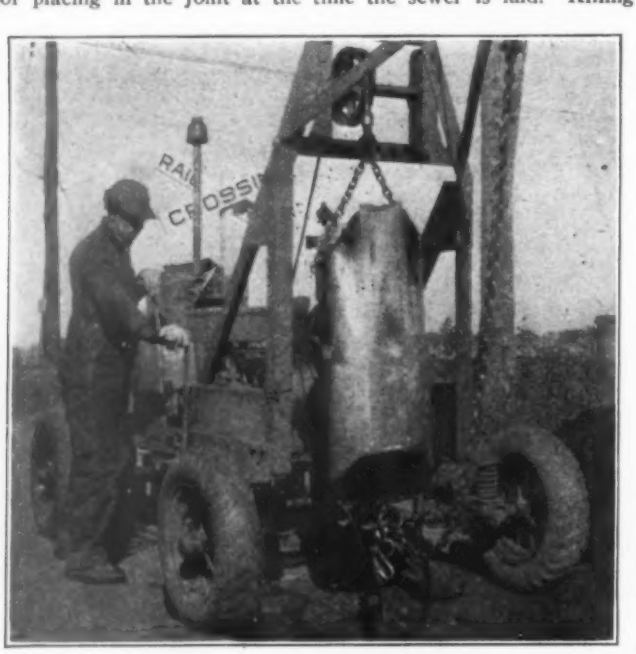

Fig. 1—Turbine Sewer Cleaning Machine at Bloomington, Ill.

Sewer Cleaning

Flushing.—Although not always positive, flushing of sewers is a convenient method of scouring out minor grit deposits and grease accumulations.

Surface water discharges during rains provide adequately for flushing storm and combined sewers, although supplementary flushing by fire hose is employed at Birmingham, Mich., Portland, Ore., and Sacramento, Cal., in conjunction with other cleaning operations, to clean lateral lines and to reduce odors at manholes in extended dry weather seasons. Routine flushing is a general practice in maintaining separate sanitary sewers but the frequencies reported vary from monthly to annually. At Orillia, Ontario, where the sanitary sewers have a minimum

slope of 5 per cent, Engineer L. G. McNeice indicates that annual flushing is practically the only maintenance required. In some cases, as at Ithaca, N. Y., and Kahoka, Mo., routine flushing is limited to critical lines on flat grades, which are flushed every two or three weeks. At Kahoka, some shallow lines are flushed after midnight by means of a time-clock actuated electric valve on the water service, giving a discharge of twenty minutes' duration.

Many old sewer systems were equipped with automatic flush tanks, located at the upper ends of laterals to assure scouring of deposits. Present practice is to design sewers with adequate slopes and the use of such devices is confined to lines in which flat grades are unavoidable. A number of contributors to this article indicate that old flush tanks have been abandoned; others that they are still used occasionally.

From a practical study of the hydraulics of sewer flushing, Watson[8] concludes that the *depth* of the flushing flow in the sewer is equally as important as the velocity. This accounts for the fact that flushing is most effective when the sewer is plugged at the lower manhole, the fire hose used to loosen grit deposits and grease accumulations and, after a head of sewage and water is built up, the plug is suddenly removed to release the flush. Kilpatrick (Rolla, Mo.) emphasizes the importance of blocking the sewer in connection with flushing operations. Sewer "bags," having a hose connection at one end and a nozzle in the other, are available for plugging the sewer and adding flushing water at the same time.

Satisfactory flushing by means of "water wagons" is accomplished at Los Angeles[9] and Lower Merion Township, Pa.[10] In the latter case, water is discharged at the upper manhole from a 625-gallon steel tank mounted on a truck and having a 6-in. drain valve. Discharge is so rapid that an 8-in. sewer is completely filled, giving an effective flush of 500 to 800 feet of sewer.

Hydrogen sulfide formation in sewage is accelerated by the presence of septic sludge deposits in sewers. Bowlus[11] reports that sulfides are definitely reduced after flushing, indicating that the practice is beneficial in reducing odors at manholes and treatment works as well as in reducing damage to sewers and concrete structures.

Removal of Roots.—For cutting and removing root growths in sewers up to 15 in. in diameter, flexible type rods and cutters appear to be very popular, because of the time saved, compactness of the equipment and small labor requirement. An augur-like cutter is used, which is rotated by twisting the rods as they are forced down the sewer. The equipment can be operated easily with two men if the power drive is used, or four men if the rods must be twisted manually. Another advantage of this equipment is that it can be fed into the sewer from ground level and does not require entry into manholes. Accumulations of roots removed at Cimarron, Kan., are shown in Fig. 6.

For removing roots from larger sewers, or particularly obstinate ones from small sewers, cutting drags are pulled through by cables and winches, either power or manually operated (Fig. 7). This procedure is positively effective, and in many cities is the only method used.

At Ocean City and Merchantville, N. J., every effort is made to prevent recurrence of root growths which are removed from sewers. Steelman at Ocean City reports that defective joints admitting roots are immediately located and repaired and some very troublesome lines have been relaid in iron pipe. Poplar and willow trees causing trouble at Merchantville are removed. Permanent control of roots in house service lines is the aim at Birmingham, Mich., where the city provides 6-in. cast iron pipe with leaded joints to the property line and requires not less than vitrified pipe with asphalt mastic joints inside the property. In case of root stoppage in old cement jointed vitrified pipe services (in the street), the city relays the service to the property line in cast iron pipe for a permit fee of $15.00.

Removal of Sand and Grit Deposits.—When flushing does not produce adequate results, sand buckets or scoops pulled through by the cable and winch outfit are universally depended upon for removing deposits of grit. This equipment (Fig. 1) is positive in effectiveness, regardless of the size of the accumulation.

Where the deposit is not too large, the "Turbine" cleaner which has a water powered, rotating cutter is effective. This device, dragged through the sewer by cable and winch, combines water jet flushing, cutting and dragging into one effective operation.

Rawn[7] describes an ingenious sewer "hoe" used by the Los Angeles County Sanitation Districts for removing grit accumulations from sewers over 30 in. in diameter with a minimum of labor. The device is propelled through the sewer by the pressure of sewage behind it and the invert and sides of the pipe are scoured as it moves. For sewers of 15 to 30 in. in diameter, a beach ball inflated to approximately the size of the sewer is used effectively in the same fashion as the "hoe."

Removal of Grease Accumulations.—Unless of industrial origin, sewer stoppages by grease are confined almost entirely to house services; however the capacity of larger sewers is often reduced due to the development of a grease lining in the pipe.

Flat sewer tapes with various kinds of cleaning tools are used for removing grease obstructions from house connections at Ocean City, N. J. Large sewers give no trouble here. At Atlantic City, N. J.,[5] the most useful device for opening house

Fig. 4—A Few Roots from a San Diego Sewer.

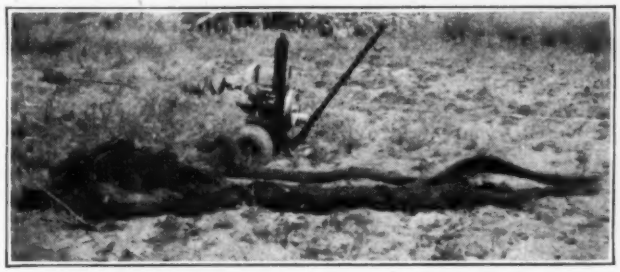

Fig. 5—Not a Sea Monster—A Root Removed in San Diego by Power Driven Flexible-rod and Cutter.

Fig. 6—Root Removed by Flexible Sewer Rod Equipment at Cimarron, Kas.—City Engr. Cruisinberry at Right.

connections has been found to be a 50-ft. length of quarter-inch steel wire. The end started into the sewer has a 6-in. bend which is rotated by cranking the other end as the wire is fed, thus gouging out the stoppage.

Grease accumulations in larger sewers are loosened to some extent by flushing, root-cutting and other maintenance operations. Sewer brushes, dragged through by the ever useful winch and cable equipment, are most positive, however, and many well-trained crews always use a brush drag to finish up a line that has been dragged with other tools.

Other Cleaning Devices.—It will be noted that certain types of equipment are best suited to specific cleaning problems, yet it may often be necessary to use practically all of the equipment carried for cleaning a single line. For instance, the flexible rod and root cutter and/or detachable wooden rods may be used to partially open a stoppage to permit a cable to be threaded through for use in dragging, and several types of drags may be employed. Unusual situations will often demand considerable thought and ingenuity on the part of the maintenance crew even though they are well equipped for ordinary problems.

The sewer "hoe" and beach ball cleaners described above are examples of such ingenuity. The Los Angeles County Sanitation Districts, where these labor-saving implements were devised, makes root cutting drags for 12 to 36-in. sewers from steel pipe[7]; sewer brushes at Ithaca, N. Y., are made from old street-sweeper brooms; a knot of old chain has been found to constitute a serviceable root cutter and drag at Portland, Ore.; a 15-in. root cutter was made to service an 18-in. sewer at Urbana-Champaign, Ill., by wrapping the periphery with barbed wire, further illustrating actual practice in meeting local problems.

Ground Water Infiltration

Although most ground water infiltration results from faulty sewer construction (poor joints or failure to use proper pipe through critical water-bearing soil formations), good maintenance and operation practices can reduce this problem. In referring to infiltration, nearly all of the contributors to this article mentioned the relatively new asphalt mastic jointing compounds as a curative measure, either in explaining why there was no serious infiltration problem or describing how it is being minimized in new extensions or old sewer repairs.

Where there is ample sewer capacity, gravity flow and no sewage treatment works, there is an inclination to disregard infiltration to some extent. Usually the allowance for infiltration in the design of separate sanitary sewers is only nominal but such leakage often proves to be of serious consequence, as at Ithaca, N. Y., where it amounts to 100 to 400 per cent of the dry weather sewage flow due to broken pipe and poor joints. Superintendent Carpenter indicates that correction can be accomplished only by replacement of the defective lines by cast iron or other suitable pipe.

Where sewage must be pumped, it has been found economical to locate and actually replace those lines admitting large amounts of ground water. This has been done at McHenry and Fox River Grove, Ill., Rolla, Mo., and elsewhere.

Steelman (Ocean City, N. J.) and Bridges (Kahoka, Mo.) point out the necessity of careful control and inspection of house connections to minimize infiltration. The sharp increase in flow in sanitary sewers during rains is usually caused by illicit downspout connections which are most difficult to control since many of them are changed after the installation inspection is made. Constant vigilance, public education and rigid enforcement of ordinance provisions are the only possible means of minimizing this source of extraneous water. Kahoka, Mo., and Birmingham, Mich., sewer users are required to comply with strict specifications for workmanship and materials in constructing house sewers.

Maintenance of Appurtenant Sewerage Structures

Aside from ordinary inspection and replacement of broken manhole covers, it is important that manholes in unimproved or semi-permanent streets be maintained at the proper elevation. Considerable damage to such streets is done when an attempt is made to find a manhole which has been covered. Rattling manhole lids often create a nuisance and correction has been accomplished by: application of tar or asphalt around the entire rim or at three or four points[10]; gaskets of rubber, jute or canvas; machining of the lid and casting; use of mechanical locking lids or low center of gravity types. Anderson,[1] after trying several methods, now uses a tape packing made for the purpose which is placed around the entire periphery after thorough cleaning of the casting.

Other appurtenances common to separate sanitary sewers are inverted siphons, creek crossings and flush tanks. Inverted siphons must be inspected frequently as they are readily clogged by accumulations at the inlet or grit deposits in the siphon pipes. Two siphons on intercepting sewers at Champaign-Urbana, Ill., are inspected at least weekly and cleared of inlet accumulations. Three siphons at Ithaca, N. Y., are flushed out every four months. Creek crossing structures are generally checked following wet seasons to ascertain erosion damage, replace protecting rip-rap or make repairs. Flush tanks maintained in regular service are inspected monthly and afforded cleaning and adjustment.

Frequent cleaning of catch basins on storm or combined sewer systems is justified by the protection they provide against grit deposits in the sewers. Practice appears to be to clean these at least annually where paved streets are drained and more often when streets do not have a permanent surface. Street inlets are inspected and cleared after every rain at Rock Falls, Ill., to assure good street drainage. Storm water overflows are inspected and given necessary attention at least once monthly at Birmingham, Mich., and Bloomington, Ill., with more frequent attention being accorded in wet seasons. Sewage flow regulators and adjustable overflows in combined systems are best attended during high flows so that they may be adjusted to actual operating conditions.

Regulation of Use of Sewers

Probably no other public utility is misused to so great a degree as is the sewer system, yet there is always readiness on the part of the public to criticize faulty operation. This condition is no doubt largely due to the lack of public education and to the failure of city officials to adopt and *enforce* proper ordinances controlling the usage of sewers. Such an ordinance does no good if merely filed among the dusty archives of the municipality—it must set forth proper practices, contain adequate penalties and be enforced without hesitancy when courteous requests for cooperation are ignored.

Anderson[1] points out that the best way to obtain public cooperation is to definitely allocate responsibility for house sewer connections to the property owner, requiring him to pay for any maintenance work necessary on these lines. Many eastern cities have established a policy of accepting responsibility for all sewers outside the curb, which practice appears to have several advantages. The Atlantic City Sewerage Co.[8] requires a trap on each house service at the curb and responsibility in each case is determined by examination of the trap. The company services all sewers outside the curb and local plumbers perform at the property owner's expense any work needed from the curb to the house.

Among the more important items warranting inclusion in the sewer ordinance are:

1. Control over location of certain trees (poplar and willow) which might cause root stoppages, including authority to remove such trees found to cause trouble.
2. Prohibition of downspout and similar surface water connections from separate sanitary sewers.
3. Provision for detailed inspection by competent personnel of all house service installations. Also rigid specifications covering workmanship and material in house services.
4. Requirement of suitable preliminary treatment facilities in commercial and industrial concerns to prevent damage to sewers. Wastes commonly controlled for this purpose are: (a) Greasy wastes from restaurants, packing plants, etc.; (b) oil and dirt from automobile filling stations and wash racks; (c) Inflammable and explosive wastes from cleaning establishments; (d) wastes containing excessive solids, such as spent grain from breweries, paunch manure from packing plants, ashes, garbage, etc.; (e) corrosive wastes, as those from metal galvanizing and pickling plants.
5. Requirement of suitable preliminary treatment facilities in industries to prevent interference with sewage treatment plant operation.
6. Provision for stern penalties for malicious damage by vandals.

A combination grit and oil trap recommended by the South Dakota Board of Health[9] for use on sewers from garages, filling stations and automobile wash racks is shown in Fig. 7. The oil problem is successfully met at Baltimore[2] by requiring by ordinance that such waste be stored on the premises until collected periodically for disposal under direct control of municipal authorities. The provision of a convenient means of disposal of the oil eliminates need for policing garages and similar establishments.

After a bad fire caused by waste oil and gasoline dumped to sewers at Aurora, Ill., Superintendent W. A. Sperry acted to prevent a recurrence by means of newspaper publicity and direct contact with industrial sources of volatile wastes. The latter was accomplished by a plant-to-plant canvass of 245 industrial and commercial establishments, during which a verbal notice

was given a responsible representative of each concern, a poster epitomizing the sewer ordinance was left and a signed acknowledgement of each visit was obtained. The survey cost $100 and appears to be good insurance against future damage, although it must probably be repeated after several years.

Sewer Ventilation

Ventilation in sewers is necessary to dilute and purge the system of gases which are inflammable, explosive, asphyxiant and toxic. In warm climates where hydrogen sulfide is often a problem, ventilation is also beneficial in controlling disintegration of concrete sewers and structures because (a) the concentration of H_2S in the atmosphere and (b) collection of moisture on exposed surfaces, are reduced.

The degree of effective ventilation in a sewer is usually dependent upon the amount of vent openings and the movement of air across the openings. Thus, it appears that natural ventilation is at a minimum on still days.

Forced ventilation has been found justified in large outfall sewers at Los Angeles[9] and several ventilation stations are in development. Ordinary ventilation practice is probably represented by the procedure at Lower Merion Twp., Pa.[10] "Ventilating covers" having eight 1-in. openings are placed at the upper ends of all lines and approximately at each third manhole, with consideration being given to surface water drainage and proximity to points at which odor might be troublesome, when selecting locations. Buckets are hung beneath ventilating covers for the purpose of catching debris which might pass through the openings.

To guard against fires and explosions and to eliminate conditions dangerous to sewer maintenance personnel, the city of Los Angeles[9] has a gas survey crew which systematically checks the entire system, making observations at about 60,000 manholes per year. Results of various gas detector tests are recorded and used as basis for correction of dangerous conditions. When the presence of illuminating gas is suspected, the utility company is immediately notified so that any gas main leak may be repaired.

Design and Construction Items Facilitating Maintenance

Good design and careful construction of a sewer system will reduce maintenance to a minimum and expedite such work as is necessary. There has been sufficient experience at this time to substantiate present methods of ascertaining sewer sizes and grades, yet there is often a tendency to violate the limitations of good practice, particularly with respect to grades. Every effort to avoid capital and operating costs of pumping stations is certainly justified, but consideration must also be given the less satisfactory service and everlasting maintenance expense which accompany the installation of sewers on flat grades. Where moderate reductions in slope are logical, provision of adequate, suitable flushing facilities constitutes good practice.

The prevalence of difficulties from roots and ground water infiltration is ample proof that too much care cannot be taken in specifying and installing permanently tight joints. This fact, of course, is generally appreciated and modern jointing methods and materials are already demonstrating their superiority. Careful specification and performance of back-filling is also important in preventing crushing of pipe and movement which results in opening of joints. The use of especially suited pipe and construction methods in sections where foundation conditions are bad or where excessive ground water is present, has been proven to be good economy, even though more expensive in first cost.

Other design and construction details suggested by maintenance personnel as being of importance to their functions are the following:

1. Design of junction chambers so that back-water areas of low velocity, causing deposition of grit, are avoided.
2. Design of storm water overflows so that they are not accessible by vandals.
3. Catch basins of ample size at storm water inlets draining unpaved streets.
4. Complete consideration of local conditions when selecting the type of pipe used for sanitary and industrial sewers.
5. Spacing of manholes not more than 350 feet apart.
6. Lateral sanitary sewers of not less than 8 inches diameter.
7. Smooth flow without splashing or turbulence at manholes or appurtenant structures. (Important where hydrogen sulfide might be a problem.)
8. Diversion and regulator devices of simple design and capable of convenient adjustment.

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Fig. 7—Manually Operated Sewer "Drag" in Ithaca, N. Y.

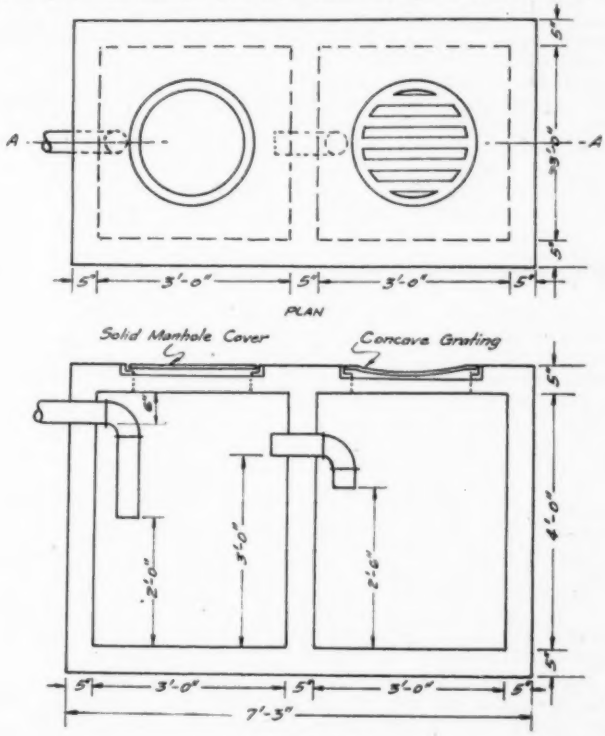


Fig. 8—Combination Oil Trap and Grit Basin for Garages and Filling Stations. Recommended by South Dakota State Board of Health.

SEWER FLUSHING

Good and Indifferent Practices

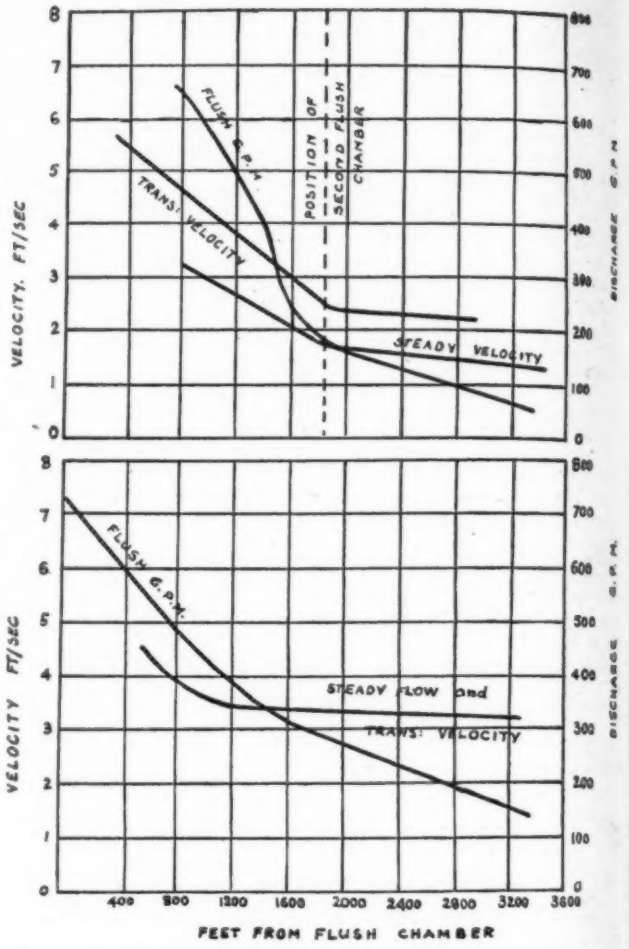
By JOHN D. WATSON

Consulting Engineer, Ruislip, England

This article reveals much pertinent to "Sewer Flushing" practices and presents what may be considered satisfactory flushing and what will prove a waste of effort and funds. The all important depth of flow in flushing, as compared to velocity flow without the needed depth, is pointedly emphasized. If we interpret correctly, many readers will find it necessary to consider some of our existing pseudo-flushing practices as little more than sewer "rinsing," after reading the depth—velocity discussion by Mr. Watson—an authority with a wealth of experience and years of observation to draw upon.

The basic condition upon which calculations for sewer flow should be made is that the sewer have a self-cleaning velocity. In other words, it should never tend to silt up even though the dry weather flow condition persists for long periods while at the same time it must be capable of taking storm water, unless it is wholly diverted from it. Provided they are properly constructed it is not usually difficult to give sewers a sufficient fall for this condition to be fulfilled. Main sewers will work with little or no trouble when laid on a grade of 1:1000 or less and, when the London Main Drainage was designed some 70 years ago, experiments showed that a velocity of 1½ miles per hour was sufficient, and very little cleaning is necessary in these sewers today. They vary from the familiar oval section of 4-ft. x 2-ft. and 8-in. to circular sewers of 12-ft. diameter. They are mainly built of brick.

Trouble is rather more likely to occur in the smaller branch sewers which have to be put in of a size to allow of increasing population so that for perhaps 10 or 20 years, normal flows are insufficient to maintain a self-cleansing velocity; and, while it is usually possible to divert surface water into them, it usually has to be kept out in order to save pumping and purification costs. The system adopted at one time at Hamburg, of constantly flushing the main sewers from a small river, enabled them to be laid at 1:3000, and to be run practically half full continuously, but that principle has rarely been adopted. The usual practice, when artificial flushing is resorted to, being either to provide gates to dam back the flow and then to release the pent up sewage for the purpose; or the use of tanks operated by an automatic syphon, the latter arrangement being as a rule the better one.



Curves Revealing Relationships Between Depth of Sewer Flush (Rate of Flush Discharge) and Effects Down-Sewer

The Great Importance of Depth in Flushing

When arranging for it the important points to bear in mind are, that the flush is not going to be effective over any great distance, and that it is the depth of flow over the invert of a sewer which is the most effective in moving the material which is the main cause of obstruction. That of course, is the condition intended to be provided by the oval sewer, silt being usually the main cause of the trouble in the present connection. In the form of road detritus, though it may reach the sewers mainly in times of storm when there should be sufficient velocity to carry it to the outfall, road detritus in the average condition has been found by experiment to require a velocity of nearly 1-ft./sec. to keep it on the move and if small pieces of broken stone and similar material get into the sewer (which by some unaccountable means they do) such, according to size, will require a velocity of 2½ to 3½-ft./sec. to move them. Incidentally, it is such obstructions in the first instance, as a rule, which cause a general obstruction to build up.

Such material always moves along with a speed of travel less than that of the stream (usually not more than half) and though 2½-ft./sec. flow velocity may move a piece of stone it will only barely do so in 1-in. depth of water. But, if the depth be increased to 6-in. it will roll along quite easily at 2-ft./sec., confirming the contention already made that it is the depth of liquid in the sewer that is the really important factor in keeping it clean. Therefore, the conclusion to be reached, is that, in circular sewers at all events and more particularly in the average branch up to 30-in. dia., the basic cause of silting is *insufficient depth* of flow *rather than velocity*; and, especially is this evident in lateral sewers which only receive intermittent discharges from the dwellings connected to them. Thus, deposits commence which ought to be periodically flushed away because if they are not removed, although they might not immediately render the sewer inactive, they cause a filmy growth (slime) to appear on the pipe wall. This growth in turn further reduces the velocity, and so matters go from bad to worse with the additional evil of the sewage becoming septic and producing large volumes of sewer gas, with its well known attendant evils.

This can be demonstrated in a simple manner by purposely putting some coarse sand or fine gravel in a sewer. Then it will be found that while motion is set up by dragging action, the particles are more or less lifted up into the stream and further motion is carried on by the added effect of suspension. The greater volume of material is naturally carried in the lower layers of the stream, the total quantity being proportional to the depth. Motion, too, will be seen to be from the sides of the sewer towards the centre, the major portion of the suspended matter being carried along the centre of the stream. The amount and the size of the material being carried in suspension

depends upon the velocity of the stream and its depth of flow. But, to a much greater extent depth is controlling, because in appreciable depth of liquid the particles are thrown to a greater height; and, as the velocity of descent of the particles is the same in both cases, the deep stream carries the particle further owing to the greater opportunity of remaining suspended.

Effects of Flushing

The conclusions to be reached, therefore, are that as a general rule it is advisable to provide means for flushing pipe sewers when they are laid at flatter gradients than those listed below:

12-in.....1:300	21-in.....1:600
15-in.....1:400	24-in.....1:700
18-in.....1:500	27-in.....1:800
30-in.....1:900	

Between 2,000 and 3,000 gallons at a flush, according to the size of the sewer and provided it is released once or twice every 24 hours, usually suffice. In any event it should be an amount that, when it does come into the sewer, practically fills it at that point. This, because the depth of the flushing wave near its point of origin decreases as it moves downstream to a point at which the depth and velocity are but little affected by the discharge. As an example, one can consider a 12-in. sewer flush by a 1,500-gallon tank through a 10-in. syphon in 1¼ minutes.

On the accompanying chart the upper set of curves relate to such a sewer laid at 1:630. One curve reveals transmission velocity, the other steady-flow velocity. As regards the former, the rate of transmission, at the commencement of the flush and at different distance from the flushing chamber, is that which would give the maximum scouring velocity, assuming the flush to be discharged into an empty sewer. This velocity lasts but a few seconds and its effect reaches but a short distance. In the matter of the steady-flow velocity, during the period when the maximum volume of flushing water is passing at different distances from the flushing chamber, it will be observed that this velocity lasted for a minimum period of 1 min., the period increasing with the distance from the flushing chamber. There is also a third curve which reveals the maximum volume of flushing water in gallons per minute at different distances from the flush chamber. From this curve, the effect of varying the amount of flush water discharged per minute can be determined. The lower set of two curves, in comparison, relates to a 9-in. sewer having a flush of 750 gallons for one minute.

Facts and Conclusions

The principal facts which become apparent from an examination of these curves are that:

(1)—The velocity dies off rapidly at first until it attains a certain value after which the diminution is small. As a result the flush is transmitted over an appreciable distance, probably about one mile.

(2)—With flat gradients, the velocity when the maximum volume of flush water is passing is less than the rate of transmission at the commencement of the flush, the difference gradually decreasing as the gradient decreases until the velocities are identical—such being indicated by the lower graph.

One can conclude, therefore, that the slope of the advancing flush will gradually flatten as the distance from the flushing chamber increases except where the gradient is sufficient to secure a high velocity. It is noticeable, also, how the steady flow velocity is over 3-ft./sec. at a distance of more than 3,400 ft. from the flush chamber. If, therefore, the sewer gradient is reasonably good, though appreciably less than that above set out, a good flush (rapidly discharged) will keep a sewer clean for at least half a mile even though its capacity be considerably in excess of normal dry weather flow requirements. And that, as already indicated, is the main purpose of artificial flushing.

Maximum Flow Gage for Sewers*

The accompanying sketch pictures the type of maximum flow gage, which has been installed in five manholes in the village of Shorewood in Milwaukee County, Wisconsin.

Metcalf and Eddy, in "American Sewerage Practice" (Vol. I), under Maximum Flow Gages, describe a device that is substantially a stick with small vials attached along its length and inserted into a perforated pipe. The level of the mouth of the highest vial found full indicates the height to which the sewage has risen in the manhole. This design, however, has its disadvantages. First, the vials are breakable and entail considerable trouble in replacing. Second, it can not be used where the velocity exceeds eight feet per second.

The improvements in the Shorewood installation are:

First: It is cheap—the entire gage, made by a tinner and ready to install, costs very little.

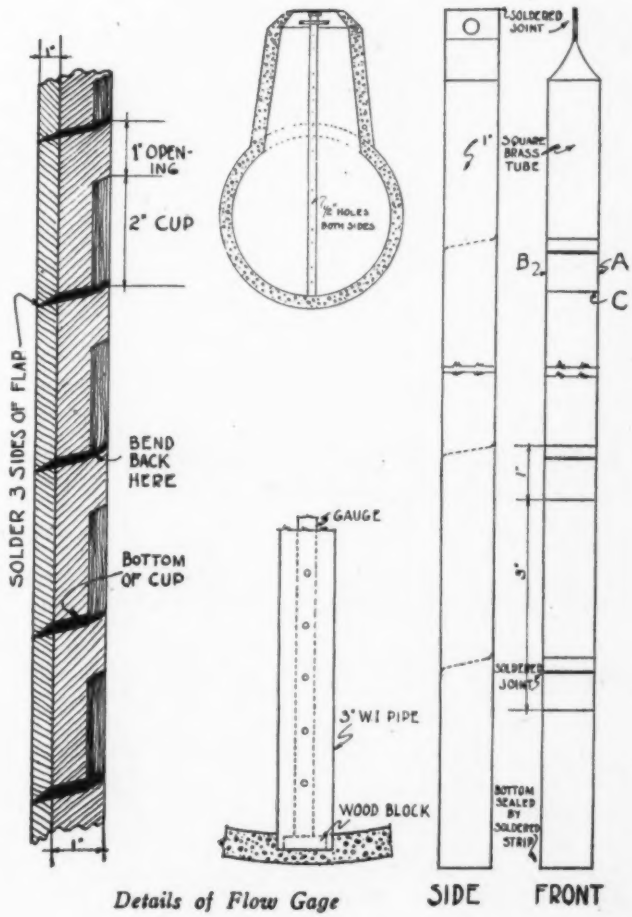
Second: It is not breakable and may be used in sewers regardless of velocity. Being made of brass or copper it is immune to corrosion.

A brief description may be helpful.—This gage is made of one inch (square) brass tubing, with one face (C on sketch) cut through at predetermined spacings. In the Shorewood design it is three inches. Then the corners are ground off on a power grinder to make edges A and B. The resulting flap is bent back and soldered in place to form the bottom of the pocket above. The block of wood is to raise the gage to the elevation of the invert of the sewer. The spacing of the pockets and the width of the mouths may be varied to suit circumstances. A perforated 2 in. W.I. pipe protects the gage.

In practice the gage has proven reliable and has served satisfactorily through several storms when the sewers were surcharged.

Credit for this design belongs to George Dewey Simms, Assistant Village Engineer, Shorewood, Wis.

*Contributed by Julius Lucoff, Milwaukee, Wis.



Details of Flow Gage

PROPER SEWER JOINTING

And Other Effective Construction Procedures to Preclude Infiltration

By WILLIAM A. GOFF

Consulting Engineer, Philadelphia, Pa.

The method of constructing joints in sewer pipes is directly related to the success or failure of the construction of a sewer system.

Those who are conversant with the many factors in the design of a sewer system, sewage treatment works, and allied units of construction, know the importance of restricting infiltration of the pipe lines to a minimum.

The extent of infiltration is not only indicative of the general character of construction of the work performed. Low infiltration leads to economy in the operation of the system and works and reserves for future use the capacity of the pipe lines and works that otherwise would have been utilized through the conveyance of needless volumes of ground water.

The effort put forth today in the treatment of sewage, which in a majority of cases requires initial pumping and in many instances secondary pumping, emphasizes the need of tighter sewers. It is readily discernible that every drop of water that enters the lines and is pumped and treated, invoives costs.

There are unquestionably numerous factors directly related to the infiltration of pipe lines, but there can be no question that the most important factor entering into this particular phase of construction is the method of constructing the joints.

In the established practice of awarding contracts to the lowest bidder, there is little or no definite assurance of the qualifications of the men who will do the work. Under prevailing conditions in public contracts a contractor is not selected on his record of satisfactory construction performance, but rather upon the price bid. While a contractor himself may be most willing to perform his contract satisfactorily, it is actually the men who work in the trench who are the keystone of performance.

The Importance of Exacting Specifications.

To afford these men the opportunity of producing satisfactory results, the engineer must of necessity know the conditions under which these men are to work, and provide in his specifications such methods of construction as will enable these men to perform their work in a satisfactory manner. In addition, the contractor must cooperate with all of his facilities in an endeavor to produce the results desired. It is this thought that I have uppermost in my mind when planning and designing a system of sewers, for I fully realize that unless the men who actually do the work are provided with a suitable method of construction, the finished product will not be satisfactory regardless of their efforts.

I have found that where a large portion of the sewer joints are to be under three or four feet head of water, that the dewatering of the trenches by the method of well points, has been the most successful means of providing favorable working conditions for the men making the joints in the trench.

Value of Trench Dewatering by Well Points.

This pre-draining of the construction area prior to the commencement of excavation does three things:

First—It provides the contractor a dry ditch in which to work and also gives the inspector a better chance to inspect the joints.

Second—It reduces by a considerable amount the need for sheeting and shoring. In the majority of cases of predraining the sides of the bank will remain standing, even in sand, with only skeleton bracing.

Third—It eliminates all needs for special construction, such as concrete encasement or cast iron sewer.

All of these things affect the cost and incidentally help to create tight joints, all of which is very important.

From Proceedings of the Twelfth Annual Conference of the Maryland-Delaware Water and Sewerage Ass'n.

After affording favorable working conditions for the men in the trench, the next step is to provide a suitable joining material and the method of its construction to obtain the desired objective.

The Most Effective Joint.

Outstanding are the bituminous joints, both hot and cold. Basically they are composed of coal tar or asphalt, mixed with powdered inert materials and either poured into the joint while hot and allowed to cool, or preformed joints inserted in the joint space and pushed in place when the pipes are assembled.

Jointing with hot poured compounds has the advantage of completely filling the annular joint space, more permanent adhesion to the pipe sides, and a degree of resiliency which will permit slight movements of the pipe line.

Preformed joints have made their appearance on the market and have been used with various degrees of success. One preformed joint, consisting of collars of felt impregnated with these asphalt compounds, made in sizes to fit the commercial pipe sizes, is slipped over the spigot end of the pipe and forced along with the pipe by means of a mechanical jack, into the bell of the receiving pipe; the natural resiliency of the preformed joint distorting to fit the shape of the bell and spigot. Another preformed joint which has been used with good results is made by the use of metal dies clamped in the bell and around the spigot of pipes and poured with hot compound prior to lowering the pipe into the trench. At the time of assembly the two preformed collars are painted with a solvent and pushed together the solvent causing the collars to fuse and thus form the joint.

Jointing Experience

The type of joint which I have been using for the past seven years is the result of numerous experiments and actual field tests, and consists of the following:

Oakum packing of approximately 1-inch in depth.
A hot bituminous joint of approximately 1½ inch in depth, and an outside cement mortar fillet wrapped in a muslin cloth tied tightly in place.

Such a joint sounds complicated, but my experience shows that after the ditch-men become experienced, the joint can be made rapidly and consistently perfect. Perhaps this joint does add a few cents to the per foot cost of the sewer, but what of that. The owner is buying a sewerage system and he wants a good one. It is distinctly worth while to avoid infiltration and all will agree that there is only one time to get tight construction and that is when the sewer is built. Any small initial increased cost of construction is soon compensated by the economies possible where the infiltration is negligible.

Laying Specifications.

In the construction of the joint I specify, the pipe be laid by two men, one holding the spigot end of the pipe in a "U" shaped sling consisting of perhaps two strands of jute at the end of the pipe while the other man pushes the pipe home from the bell end. After the pipe is home the front man wraps the oakum over the pipe and pushes it in place with a caulking iron, so as to provide proper space for the bitumen, while the back man tests the pipe for elevation with a grade rod from the line above and checks for line by a plumb bob from the same line, and makes such adjustments as necessary. He then moves forward, checks the subgrade for elevation and excavates bell and a length four inches longer than the circumference of the last pipe laid and determines if it is free of water. The next pipe is then handed down into the ditch and laid as before. The top man, before handing the pipe down, ties on the bell end of each pipe a piece of muslin with a width of six inches greater than that of the bell and a length four inches longer than the circumference of the bell. This cloth has been torn to provide tie strings at each of the four corners. Another man follows behind and places around each bell a runner fastened

with a clamp at the top. Into this runner mouth he pours the hot joint compound, being careful to keep runner filled at the top and see that there is no leak at bottom or sides.

When cold, the runner is removed and the muslin band pulled out under the joint and completely filled with a cement-sand mortar (1:2) to form a 45° fillet around the outside of the bituminous joint. The mortar is pushed under the pipe to fill the band and the cloth band is then pulled tightly up and tied with the two remaining strings across the top of the pipe. The joint man then encircles the pipe with his hands and makes sure that the muslin band is completely packed with mortar, *especially at the bottom*, and that the band is tight. He then draws his hands upward, pressing the joint and dresses the top. Of course the mortar must be fairly stiff. It is not as complicated as it sounds, and contractors who have worked under me are generally enthusiastic after their men get the swing. It makes a *good* joint. The men know it. The inspector can check it. The contractor can see it and knows that future infiltration trouble is ended.

Features of This Joint.

The joint itself is correct. The oakum prevents the bitumen from getting into the pipe. The runner forms a tight channel for the bitumen which fills the annular space, adheres to the pipe surface and forms a tight joint. The bitumen can be readily inspected when the runner is removed. The cement collar reinforces the bitumen and provides maximum reinforcement where there is the greatest chance of a slip in the bitumen joint. That is as always, at the bottom. If by accident there should be a poorly poured bitumen joint the tightly packed cement mortar fillet will be forced into the hole and the rag will hold it there while the mortar hardens. The mortar fillets tends to give rigidity to the joint. The rag prevents backfill on a freshly made joint from disturbing the joint.

Results.

Results in the use of this joint have proven remarkably successful. Nowhere have contractors failed to meet the severe infiltration limitations I have set up in my specifications where I have used this joint.

In Harrington, Delaware, for instance, we constructed 8.08 miles of sewers, of which about fifty per cent was wet trench with an infiltration only 6.6% of the allowable.

In Berlin, Maryland, we constructed 7.97 miles of sewer of which 30% was wet trench with an infiltration only 7% of the allowable.

Other Records	Miles	Percent of allowable
Spring City, Pa.	9.59	27
Florence, N. J.	12.14	20
Conshohocken, Pa.	25.08	3
Georgetown, Del.	8.36	21
Clarks Summit, Pa.	18.99	68

Think of it, even in the last case we have a 19 mile system with a total infiltration of only 3,790 gallons a day, or less than three gallons per minute. Then consider that a ¼-inch hole under a two foot head of water will give a flow over one-half gallon per minute.

The infiltration limits I specify are as follows:

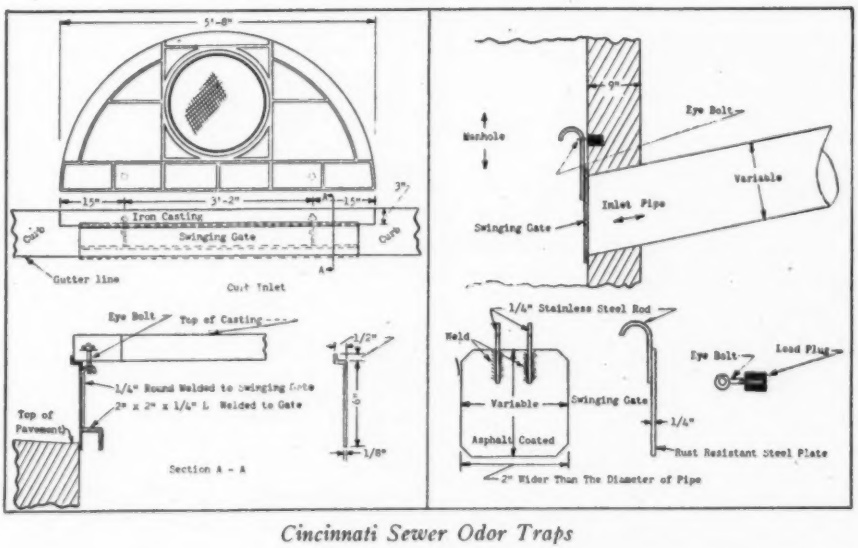
Size of T. C. Pipe-inches	Gallons-per mile in 24 Hours
5— 6	4,000
8	5,000
10	6,300
12	7,500
15	9,500
18—36	15,000

In the above mentioned list of recent jobs well points were used on Harrington, Delaware; Berlin, Maryland; Florence, New Jersey, and Georgetown, Delaware. In all of these instances quicksand was met and in no case did we use any special construction method.

Backfilling.

In backfilling the trench care must be taken to use only fine soft earth around the pipe in order to minimize the possibility of cracking the pipe. This initial backfill should be placed equally on both sides of the sewer to prevent dislodging and be carried at least one foot above the top of the pipe and carefully tamped to insure equal solid side foundation around the sewer pipe.

SEWER ODOR TRAPS FOR MANHOLES AND INLETS



Cincinnati Sewer Odor Traps

To hold in sewer gases and prevent the emanation of objectionable sewer odors from storm inlets to combined sewers and sewer manholes the here sketched swinging flap-gate arrangement has been designed and installed in Cincinnati by the Department of Public Works.

The trap for inlets (left) consists of a swing gate of ⅛ in. metal, fabricated and installed as sketched. The gate flap, reinforced and weighted with an angle iron welded across the bottom, opens inward under force of storm water and returns to closed position thereafter.

The trap for manholes consists of swing gates on all inlet sewers entering the manhole (right) and are apparently intended to preclude odors and gas from working back up-sewer rather than to prevent odors emanating at the top of the manholes so equipped. Naturally, the latter source of sewer odors can be corrected by plugging what appear to be of more hazard and detriment than of help—the vent holes in manhole lids—and employing rattle preventing "Tapax," or its equivalent, for sealing the space between the lid and the manhole frame.

It will be noted that non-corrodible metal and bituminous coating are used to preclude corrosion of the flap gates and hinges employed in manholes.

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Everdur Metal

For Sewage Treatment Equipment, Reservoir and Water Works Service

FOR SEWAGE TREATMENT EQUIPMENT

Air filter of secondary room of the Ward's Island Sewage Disposal Plant. Framework of filter structure and filter holders are welded and bolted Everdur Sheet and Strip. Retaining mesh for filter is perforated Everdur Sheet. Fabricated by American Filter Co., Inc.

Control mechanicism of 12" diameter Everdur float tubes. Designed by Krajewski-Pesant Mfg. Corp. for the Ward's Island Sewage Disposal Plant, New York City.

Everdur* Metal, The American Brass Company's copper-silicon alloy, is offered as one of the most versatile materials available for the fabrication of sewage treatment equipment. It has given superior service in this field for more than seventeen years.

Everdur, made in several types, consists essentially of copper and silicon, with controlled additions of other elements. The tensile strength, in wrought form, ranges from a minimum of 50,000 lbs. per sq. in. for annealed tank plates to approximately 100,000 lbs. per sq. in. in cold worked forms. Everdur alloys all possess high fatigue resistance and resistance to corrosion equal to or better than pure copper. There are Everdur alloys adjusted for hot working and for cold work, and, with two exceptions, these metals are readily welded by either the oxy-acetylene torch or the carbon arc.

Application

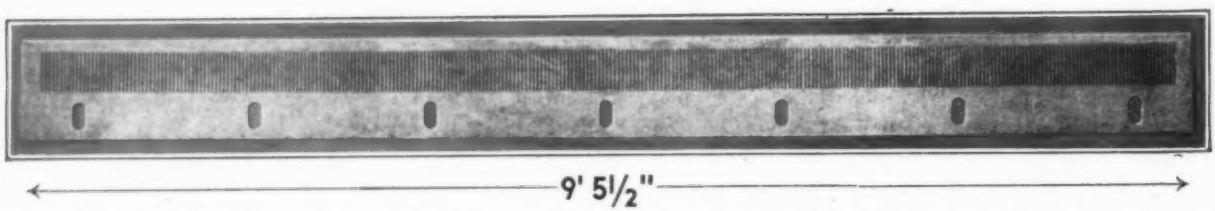
The principal applications of Everdur for sewage treatment are as follows: coarse and fine screens, swing gates, built-up sluice gates, coarse bar rack aprons, effluent weirs and scum weirs, scum baffles and brackets, troughs, screen hoppers, orifices, baskets, anchors, ladders, float gage chain, valve springs, manhole steps, walkways, bars and plates, bolts and nuts, Electrical Metallic Tubing and Rigid Conduit.

Advantages

Because of its high strength, corrosion-resistance and weldability, Everdur has effected considerable economies in equipment previously made of heavy iron castings. Relatively lightweight wrought sheets of Everdur, assembled by welding, provide much lighter, more easily operated, and more durable equipment.

Everdur Metal costs less than most high strength corrosion-resistant alloys, and not only meets many of the definitely determined corrosion problems of sewage treatment, but also provides the necessary additional protection where the forces of corrosion are variable.

*Everdur is a trade-mark of The American Brass Company. Registered in the U. S. Patent Office.



More than 100 of these Everdur weir plates, 3/16" thick, were installed in the concrete treatment tanks of the Coney Island Sewage Treatment Works. The 3/16" slots are 4" long, milled on ⅜" centers and relieved on the underside. Plates are anchored with 1" x 2½" Everdur bolts.

THE AMERICAN BRASS COMPANY

FOR RESERVOIR AND WATER DISTRIBUTION SYSTEMS

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Application

Its chief uses may be listed as: screens, screen frames, spillway fittings, flash board supports, bolts, steps, valve stems, flush box fittings and pipe. The largest use of Everdur for underwater equipment has been for concrete revetment installations in Mississippi River flood control projects. Hundreds of thousands of pounds of Everdur in the form of solid wire, stranded wire, clips, saddles, U-bolts and nuts have been used in the making, assembling and laying of the articulated concrete mattresses, which provide the river bank protection.

Advantages

Durable, non-corroding installations in masonry

Fabricating economies because of its weldability with the carbon arc and oxy-acetylene torch

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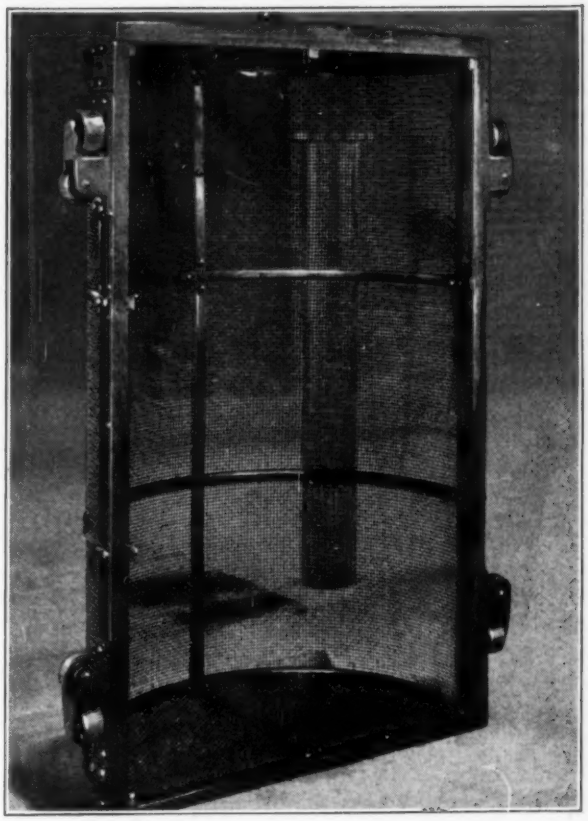

Everdur copper-silicon alloy screen frame in the gatehouse of the New Haven Water Company, New Haven, Conn.

Engineering Service

Members of the Technical Department of The American Brass Company will be glad to confer with Consulting and Sanitary Engineers regarding specific sewage treatment or reservoir and water works systems. A request for this engineering service entails no obligation.

Publications Furnished on Request

E-11 (Everdur for Sewage Treatment Equipment)
E-5 (Applications, Physical Properties and Constants)
E-6 (Everdur Bolts, Screws and Accessories)
E-1 (Everdur Casting Ingots)
E-13 (Everdur Tanks and Equipment)
B-22 (Anaconda Electrical Conduit)

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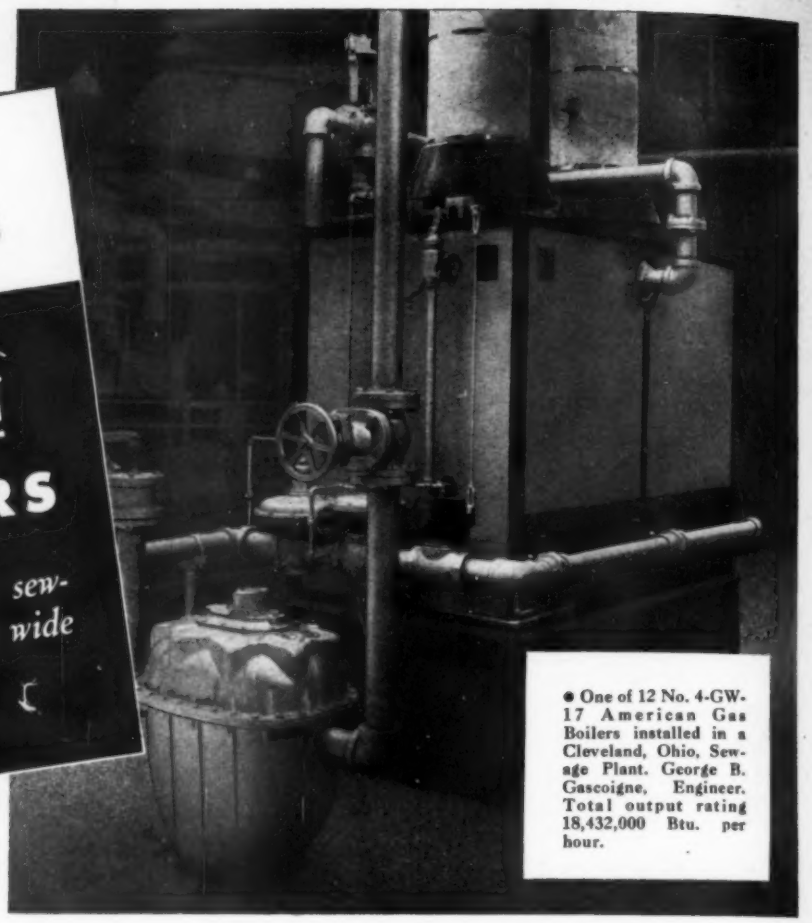

● One of 12 No. 4-GW-17 American Gas Boilers installed in a Cleveland, Ohio, Sewage Plant. George B. Gascoigne, Engineer. Total output rating 18,432,000 Btu. per hour.

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Based on the experience of users, you cannot go wrong in specifying AMERICAN Gas Boilers for heating your sludge digesters.

These boilers are engineered for dependable, trouble-free operation and especially qualified for burning sewage gas. They are completely automatic, one valve controlling water temperature to any predetermined degree. Patented pintype sections afford the most effective type of cast iron heat absorbing surface. Controls are available to accommodate any desired system of gas, temperature or pressure regulation. A wide range of sizes meets all requirements. Detailed information on request.

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Steam	Water	BTU. per Hour	Sq. Ft. Steam A.G.A. Rating	Sq. Ft. Water A.G.A. Rating	BTU. per Hour	Cu. Ft. 700 BTU. Sludge Gas	Over-all Hght.	Width Front	Depth
.....	1-GA-4	31,500	.....	210	39,350	56	40 ½"	14 ½"	22 ½"
.....	1-GA-5	42,000	.....	280	52,500	75	40 ½	14 ½	25 ½
.....	1-GA-6	52,500	.....	350	65,600	94	40 ½	14 ½	28 ½
.....	2-GA-4	63,000	.....	420	78,750	113	45 ¾	19 ½	22 ½
.....	2-GA-5	84,000	.....	560	105,000	150	45 ¾	19 ½	25 ½
.....	2-GA-6	105,000	.....	700	131,200	188	45 ¾	19 ½	28 ½
.....	2-GA-7	126,000	.....	840	157,500	225	45 ¾	19 ½	31 ½
.....	4-GA-9	168,000	.....	1120	210,000	300	45 ¾	28	38
.....	4-GA-11	210,000	.....	1400	262,500	375	45 ¾	28	44
.....	4-GA-13	252,000	.....	1680	315,000	450	45 ¾	28	50
0-GS-4E	.....	61,200	255	.....	76,600	109	40 ½	16	33 ¾
0-GS-5E	.....	81,600	340	.....	102,000	146	40 ½	16	37 ¾
0-GS-6E	.....	102,000	425	.....	127,500	182	40 ½	16	41 ¾
0-GS-7E	.....	122,000	510	.....	153,000	218	40 ½	16	45
1-GS-4	1-GW-4	146,000	610	980	182,500	261	54 ½	35*	33 ¾
1-GS-5	1-GW-5	186,000	775	1240	232,500	332	56 ¾	39*	33 ¾
1-GS-6	1-GW-6	225,000	940	1500	281,500	402	56 ½	43*	33 ¾
1-GS-7	1-GW-7	265,000	1105	1770	331,000	473	57	47*	33 ¾
1-GS-8	1-GW-8	305,000	1270	2030	381,000	545	59 ¼	51*	33 ¾
1-GS-9	1-GW-9	345,000	1435	2300	431,000	616	58 ½	55*	33 ¾
1-GS-10	1-GW-10	384,000	1600	2560	480,090	686	59 ¼	59*	33 ¾
1-GS-11	1-GW-11	424,000	1765	2820	530,000	757	59	63*	33 ¾
4-GS-6	4-GW-6	480,000	2000	3200	600,000	857	69	53	52
4-GS-7	4-GW-7	576,000	2400	3840	722,000	1030	69 ¾	58	52
4-GS-8	4-GW-8	672,000	2800	4480	840,000	1200	71 ¾	62	52
4-GS-9	4-GW-9	768,000	3200	5120	960,000	1372	72 ½	66	52
4-GS-10	4-GW-10	864,000	3600	5760	1,079,000	1543	75	70	52
4-GS-11	4-GW-11	960,000	4000	6400	1,200,000	1715	75 ¾	74	52
4-GS-13	4-GW-13	1,152,000	4800	7680	1,440,000	2060	69 ¾	85	64
4-GS-15	4-GW-15	1,344,000	5600	8960	1,680,000	2400	71 ¾	93	64
4-GS-17	4-GW-17	1,536,000	6400	10240	1,920,000	2740	72 ½	103	64
4-GS-19	4-GW-19	1,728,000	7200	11520	2,162,000	3090	75	107	64
4-GS-21	4-GW-21	1,920,000	8000	12800	2,400,000	3425	75 ¾	110	64
4-GS-22	4-GW-22	2,016,000	8400	13440	2,520,000	3600	71 ¾	136	64
4-GS-25	4-GW-25	2,304,000	9600	15360	2,880,000	4120	72 ½	148	64
4-GS-28	4-GW-28	2,592,000	10800	17280	3,240,000	4625	75	160	64
4-GS-31	4-GW-31	2,880,000	12000	19200	3,600,000	5145	75 ¾	172	64
4-GS-33	4-GW-33	3,072,000	12800	20480	3,840,000	5480	72 ½	186	64
4-GS-37	4-GW-37	3,456,000	14400	23040	4,320,000	6165	75	202	64
4-GS-41	4-GW-41	3,840,000	16000	25600	4,800,000	6850	75 ¾	218	64

*1-GS shown. The 1-GW is 4" shorter

AMERICAN RADIATOR & Standard Sanitary CORPORATION New York Pittsburgh

OPERATION AND MAINTENANCE OF SMALL PUMPING STATIONS*

By GRANT M. OLEWILER
Superintendent
Sanitary Drainage, Lower Merion Township, Pa.

Four sewage pumping stations are operated in Lower Merion Township.

Station A, the Mill Creek pumping station, is equipped with three electric-motor driven two-stage horizontal centrifugal pumps. It operates against a head of 252 ft. when using its largest pump, which discharges 1,600 gal. per min. through 6,671 ft. of 12-in. force main and at smaller heads when its other pumps, one of 1,250 and the other of 1,000 gal. per min. are in use.

Station D, the Gulley Run pumping station, is equipped with duplicate electric-motor driven horizontal two-stage centrifugal pumps. Each pump operates against a head of 175 ft. when discharging 500 gal. per min. through an 8-in. force main 4,230 ft. long.

Station C, the Cynwyd pumping station, has duplicate electric-motor driven single-stage vertical centrifugal pumps, each of which operates against a head of 95 ft. when discharging 600 gal. per min. through 3,510 ft. of 8-in. force main.

Station B, the Ardmore pumping station, has duplicate electric-motor driven single-stage horizontal centrifugal pumps, each of which operates against a head of 52 ft. when discharging 833 gal. per min. through 3,310 ft. of 10-in. force main.

FROM the following descriptions it is evident that we have quite a range in sizes and although I have seen smaller stations as to head or capacity, I consider our equipment as illustrative of small pumping stations.

Pumping stations are permanent equipment and the operator or engineer in charge is urged to be ever alert to take advantage of the many new aids to operation which are constantly being found to be basically sound and well constructed.

The following divisions of the subject have been made: the pump; the motive power; auxiliary equipment; the building; personnel.

The Pump

The pump seems to be the very heart of the plant and must be considered of primary importance. It consists principally of an element to create pressure on the sewage and devices to maintain alignment of these parts.

The next time those rags get around the shaft, rubbers wind into a tight ball between the back of the impeller and the casing, a block of wood gets between the face of the impeller and the casing, with a resulting noise that makes you think the building is about to come down, or the pumping gauge shows a reduction in pressure or capacity, take a little time off and see what is happening.

What about clearances? The present-day welder in that reliable machine shop in town can do much to replace that metal which was ground off by the friction caused by fine sand in sewage. It is there—and it makes the finest abrasive possible for grinding the face of impeller blades unless of course you are one of those few operators who are blessed with the latest style non-clog closed impellers.

What about the impeller itself? Are there any visible cracks which need welding? We have had open cast-iron impeller blades crack away from the hub in a direction opposite to the thrust caused by the normal operation, so look on both sides if you wish to keep out of trouble. If the sewage is corrosive, look for pitted places which might seriously reduce the strength of the impeller or cause a loss of the design curve which is so essential for high efficiencies.

Is the impeller tight on its shaft? In one case we had all kinds of difficulty trying to keep tight an impeller on the high pressure stage. It was sent to the machinist several times before we were satisfied that it was tight. A wobbly impeller is no efficient machine and many so damage the shaft that a new one must be purchased.

How is the shaft where the packing presses against it? Those deep grooves mean that expensive packing is being wasted rapidly. If a shaft has replaceable wearing rings you are fortunate, otherwise you must balance the cost of packing and the appearance of that sloppy mess around the pump against the cost of a new shaft.

What about packing—do you use considerable? Why not talk with the salesman of the company from which it is obtained? He has many and varied installations and can probably advise a more suitable style designed to overcome just such a situation as yours.

Is the pump equipped with a water seal ring? If so, it is a valuable device for keeping sand out of the packing, but do not connect it with the potable water supply line unless proper steps have been taken to prevent back flow at all times.

Next look at the pedestal bearings. What is that material in the oil reservoir? Is it oil or a mixture of oil and sewage caused by the travel of sewage along the shaft from the packing to the oil reservoir. The latest designed pumps use slingers, which are very effective in stopping this flow. You can make duplicates of them by cutting rubber disks with a hole in the center of a diameter slightly less than that of the shaft and place them on the shaft the next time the pump is apart.

Does oil leak from around the opening through which the shaft passes? There is a rather inexpensive sealing ring made especially to prevent this.

What about bearings—are they wearing evenly or are you getting all the wear on one side? If so, it might be a good plan to try some aligning. It will pay in the reduction of power consumed as well as to make parts last longer. How did that word alignment steal into this paper? Why, that is one of the greatest troubles. We had one vertical installation which ran several years without trouble and then suddenly became a fiend. We lined this and lined that, placed steady bearings, which seemed to make it more unsteady, replaced base legs, made a new bed plate, all to no avail, several times a year that pump would go to pieces and new shafts and bearings would have to be installed. Pump men and machinists said that it was just the nature of that type and that they were constantly fixing similar pumps for other places.

One day we saw an advertisement of a flexible shaft using two universal joints, purchased one and installed it about a year ago, and—well we still have our fingers crossed. The same installation has a bearing placed in the pump casing so that it is subject to the pressure of the sewage. The original lubricant was a hard grease of the water pump type, which caused sand to become imbedded in it until it became almost a grinding collar. Black grease was recommended because of its adhesive nature, but when applied it did not have sufficient body to prevent sewage under pumping pressure from forcing itself back into the spring-feeding grease cup. Check valves were than placed in the line and operate in a very satisfactory manner. This pump operates only about thirteen minutes per run and during the time of running, sufficient grease is retained in the bearings to lubricate it so that as soon as the operating pressure is reduced the spring cup forces a new supply into place.

At the end of the pump shaft one finds a coupling. In all our present installations, except the one noted above, a rubber-bushed pin-type coupling is in use to connect the pump with the motor. These couplings had a wide flange around the outer circumference, supposedly to protect operators from the bolt heads, but some years ago the station operators found that a monkey wrench tightened on the flange would provide a good lever arm to turn the shaft when cleaning the pump. The majority of the flanges had notches broken out of them. When an 8-in. diameter coupling, with notches in its face, rotates at a speed of 1,750 or 1,175 r.p.m., it is not a nice thing to get against. In addition the notches tend to upset the dynamic balance of the shaft. These couplings have been turned down so that the flange is now very short. Cages have been placed so that the operator is not liable to touch them. Rubber bushings are replaced whenever inspection shows that the old ones have become worn.

The original installation of triplex plunger pumps at one station was never very satisfactory. The sand in the sewage constantly cut the cylinder walls and piston rings so that in a very short time the back-pressure slip became considerable and the pumping capacity would become greatly reduced. The poppet valves were a constant source of trouble and had to have their covers removed and be cleaned of rags, rubbers and other foreign material which seemed to foul them constantly.

The Motive Power

This now brings us to the motor and its bearings. While some trouble has been experienced with the bearings, it has been very slight and can be traced to poor alignment. We once walked into Station "D" and found that practically all the oil

*Presented at the Second Annual Convention of the Federation of Sewage Works Assn., New York City, Oct. 10, 1941. Reprinted from Sewage Works Jour., March, 1942, by permission.

had splashed out of the bearing when its cover had become dislodged or was not replaced correctly. Oil escaping from the ends of a motor reservoir at this station was eliminated by sealing rings.

We have been very fortunate with electric motors, one of which has been in operation since 1919, in that they are practically free of trouble, but it has been reported that years ago the windings on one motor at Station "C" burned out during the night, probably due to bad fuse protection.

Because of the increasing age of our equipment we recently purchased a megger, volt and ammeter and expect to make periodic tests to obtain information on the condition of insulation and current consumption. Articles on electrical equipment maintenance in Sew. Wks. Jour., May, 1941, "Operators' Corner," are very helpful in themselves and for the references which they contain.

While the multiple-cylinder gasoline auxiliary engines now being installed as standby power should be very reliable for small motor-driven stations, I regret that the only time I was at an automatic station where this equipment was installed, the operator opened the main switch to demonstrate the unit and although the battery turned the starting motor several times the engine failed to start, presumably because of a low battery condition. This, more than anything I have ever seen in outside stations, impressed me with the tremendous importance of proper maintenance because of the potential danger in such a condition. Had that been a real electric power failure the plant would have been out of commission until the electric power was restored.

Auxiliary Equipment

The most important auxiliary equipment is the switchboard and starter to cut the motor into the line. Two of the motors at Station "A" are started with a manual control, by which the current is turned into the motor with grid resistance in the circuit and the resistance is then cut out by a manual trolley control. Overload switches automatically break contact should an overload be applied. The most constant source of trouble on one board is the contact fingers in an oil-bath switch. Although made of laminated spring copper the contact does not seem to be sufficient to break without burning, and arc tips must be replaced frequently. For many months the men did not understand the operation of this switch and the fingers were allowed to burn to such an extent that the entire rod had to be purchased rather than the tips, which are made separate so that they can be replaced at a small cost.

The third motor, the newest, is started by an automatic industrial controller, actuated by a float-switch control or a push-button station, which brings the motor on the line by a mechanical timer which releases the resistance at the end of a predetermined interval. In addition to the regular fuses this equipment is protected by a thermal control overload switch.

Prior to the beginning of this year all operation of this station was manual, since the pumps are horizontal type two-stage centrifugal pumps located above the level of the wet well, and it was necessary to prime them prior to starting. At that time automatic air release valves and a vacuum pump were installed to make the equipment self-priming, and to eliminate almost constant trouble with check valves. A float and control switch were connected to operate the automatic industrial controller so that we are now able to operate this station on two shifts in place of three.

Tests of the pressures found in the water seal ring in the packing stuffing box on the high pressure stage of the intermediate size pump proved that a small plunger pump, which supplied water from a reservoir connected with the adjacent stream, was not delivering sufficient pressure to overcome that in the casing, with the result that the sewage was not held away from the packing. Because the stream bed had washed out since the construction of the reservoir to such an extent that water could only be obtained by placing a row of stones slightly below the inlet holes, this method of obtaining water was abandoned and we installed a small storage tank in which the supply of city water was regulated by a float valve and ample pressure was supplied by a motor-driven centrifugal pump of small capacity manufactured especially for such a use.

An amusing incident which occurred when this pump was installed illustrates the value of observation and thought. Only one wall of the station was unencumbered with other equipment and this was selected as the best possible location for the electrical control equipment for the pressure water pump and vacuum pump for priming. The installation was made in cold weather and as soon as the connections were made a test run was made. The pump motor had hardly started before the thermal control to prevent operation of an overheated motor kicked out and the pump stopped. Examination of the motor showed that it was quite cold to the touch and that the wiring had no defects but a second run again threw out the thermal control. Here was indeed a mystery until someone observed that the switch had been placed directly above a heating radiator which at that time of year was quite warm and this heat, together with the use of a thermal unit which had the lowest possible heat release recommended for this size motor, had combined to cause the equipment to refuse to operate. The next size thermal unit was obtained and no further trouble was experienced, but I can easily imagine the fun which we would have had if the installation had been made during the summer and after operating with entire satisfaction for several months, it suddenly refused to work as soon as the weather became cold enough to cause the heating plant to be forced a little more than usual.

At Station B, where the pumps also are located above the level of the sewage, automatic priming of the pump and automatic starting have also been installed. Because of the very much smaller head against which these single-stage pumps operate, no water seal rings are placed in the stuffing box, but the packing and shaft are cooled by a water jacket through which city water is circulated. Automatic stopping and starting of the motor also required an automatic shut-off for this water line. A very convenient solution of the problem was found in a solenoid controlled water shut-off valve which starts the flow of cooling water as soon as the pump is started.

Stations C and D, being newer, have the pumps located below the level of the sewage. Starting and stopping is regulated by industrial controllers actuated by a float switch connected with a float in the wet well. That "connected with a float" sounds quite simple and yet for years we were plagued with constant trouble caused by breaking of chains and cables on floats, especially since these breaks caused the pumps to run until the operator arrived in the morning. About a year ago chains and cables were eliminated and all control floats were placed on lever arms made of galvanized iron piping. Connections to the switches were redesigned after the failure of efforts to purchase switches of the type which we needed because the manufacturers stated that they could not supply such an automatic switch. We have since learned that the Westinghouse Co. makes this equipment but are now well satisfied with our own design.

Because none of our stations were provided with venturi meters or other devices to measure the inflow and pumping, we have constructed a pitometer station on the force main from each station to test the pumping capacity, but at this writing sufficient data are not available to elaborate upon their use.

Recording pressure gauges with daily charts are installed at each station and approximate reports of pumping are compiled from these data. Additional large dial pressure gauges are placed on the force main to inform the operator of the condition of his pumps from a distance.

In an endeavor to reduce the pressure fluctuations in the force main caused by the operation of the check valves and the surge of sewage, air-cushion chambers have been installed at Stations A, C and D, but it has been very difficult to maintain air in the chamber. The only case of serious flooding of the dry well at Station D was caused by the breaking of the air cushion sight glass during the night. By morning the level of the sewage had risen to the top of the motor, which had been stopped by a piece of burlap, used as a foot wiper on the bottom step, becoming wound around the shaft until it acted as a brake and actuated the overload cut-out switch. A control coil which burned at the same time may have been caused by the splash of sewage. Fortunately the motors were waterproof and after being washed out and dried for a short period, the duplicate motor, after having the old oil drained and new oil placed in the reservoir, was started without damage. The motor which had operated during the night was taken apart when inspection showed that the force of striking the sewage had either broken or badly bent the metal fins on the rotor which act as a fan to provide air circulation within the motor. New fins were placed and after tests to determine that it had suffered no other damage this motor was also placed in service.

At Station A, an automatic surge pressure-release valve has been placed on the main to relieve excess pressure by discharging back into the wet well as soon as a predetermined pressure is exceeded.

Since power charges are based upon the total demand load which may be applied at each station, the control panels must be so arranged that no two pump motors of duplicate installations may be operated at one time. This is effected by using de-energizing coils or contacts to render inoperative the starting control of the other motor during the use of one. At station A, where three pumps are to be operated, a large knife switch is

used to determine the motor which is to be placed in service. If the handle is placed in the closed position on the right hand side the smallest pump may be operated; if closed on the left hand side the intermediate size, and if placed in the open position the largest size may be used. Again interlocking coils prevent the use of the other pump motors.

In automatic stations, where no operator is present for long periods during the day and night, it is highly desirable to be able to operate the second pump at a predetermined time after the first fails to operate. We have therefore arranged float switches so that if the level of sewage in the basin continues to rise beyond the point at which the first pump should operate, a stop will engage the switch for the second pump and because of the interlock will disconnect the first pump. This has the advantage that opening of the overload switch will remove any damage to the first board without placing the station out of order, while a temporary loss of pumping capacity in one pump will be taken up by the operation of the second pump.

The Building

All our stations have a screen and grit chamber, a collecting well and a pump house.

When non-clogging impellers came into use the bar screens were removed. Trouble with foreign materials, especially in the two-stage pumps where the shaft passes through the suction elbow, has resulted in the replacement of the screens and strict requirements that they be cleaned whenever the level of the sewage on the upper side of the screen exceeds that on the lower side by an amount which will cause backing of sewage into the inlet pipe.

Screenings are placed in a compartment with a sloping floor and a drain to the screen chamber. After draining they are placed in covered cans and hauled to the township incinerator. Prior to the use of the separate drying compartment, the incinerator operators complained about the difficulty of burning this material, but since they have been used we have had no complaints.

Examination of the material removed indicates that the majority of all the screenings could very well pass into the basin without harm to the pumps. Ours is a separate system relatively free from large, objectionable materials, but this large proportion of unobjectionable material must be removed in order to prevent rags and long, stringy material from entering the pumps and fouling them and the priming equipment. For us the answer seems to lie in some form of shredder which will reduce this long material to small pieces and eliminate the cleaning of screens. Unfortunately the stations are located so near to the road that no space is available for equipment of this nature, but we are still looking and hoping that somehow it can be fitted into our plant.

Sand chambers consist of small compartments where the velocity of the sewage is broken by baffles and a large portion of the grit content is deposited. These are cleaned by the sewer repair force whenever the operators find that they are becoming filled. Materials removed are buried in large holes dug in a meadow adjoining the Mill Creek pumping station and covered for a few years, after which time the Shade Tree Commission generally finds use for the material as a soil builder. Until recently the holes were cleaned out by local gardeners who had also discovered its value, but this practice is no longer allowed.

Collecting wells vary in size from 205,000 gallons at the Mill Creek station to 7,000 gallons at the Gulley Run station. Slope on the floors ranges from 1 to 70 at Mill Creek to 1 to 4 at Gulley Run. In spite of the seemingly flat bottom at Mill Creek, sludge beds do not form to a great degree because sewage is pumped down to the level of the sump or suction hole at each run of the pumps. The sand which escapes the grit chambers is removed at least once a year and more often if an accumulation is noticed. Greases and fats which collect on the side walls of the wells are removed by scraping about twice a year, while float balls are cleaned quite often. Improvements in the operation of the Ardmore and Mill Creek basins were effected by cutting larger openings through partition walls originally designed to direct flows but which were operated to produce eddies with resulting accumulations of sludge.

The wet well at the Gulley Run station is divided into two compartments which are connected by an opening fitted with a sliding gate valve, so that either side may be used for cleaning.

In normal operation the entire flow of sewage enters one compartment and passes into the second compartment through this valve, with the result that the larger portion of the heavy material remains in the basin which it first enters, while the second side remains relatively clean. As the impeller openings on these pumps are quite small and clog very easily, the pump connected to the second or clean side is used during the night when no operator is assigned to the station, while the other pump is used during the day when a man is available to remove stoppages.

Because two of our stations have the pumps located below the collecting well it is necessary to place them in a dry well. At the Cynwyd pumping station the pumps are mounted vertically in what amounts to a basement because its only connection with the upper floor is an "L" shaped stairway. An original heating unit, consisting of a cast-iron laundry type barrel stove, was placed on the first floor but failed to provide heat for the basement. The recent installation of a hot-water boiler and a radiator along one wall of the basement, together with ample radiation on the upper floor, has dried the walls to such an extent that no moisture is evident, and has reduced materially the amount of coal consumed during the heating season. This left several months during the year when we were still troubled by the excessive moisture in the air. An exhaust fan has been installed and with this in operation a considerable degree of relief has been evident.

The Gulley Run station has horizontal pumps placed in a dry well, but in this installation the ground floor consists only of a balcony 4 ft. wide around three sides of the room. The original heater was located on this balcony but was soon found to be unsatisfactory and was moved to the lower level, where it provided only a slight improvement. We expect in the near future to re-design this plant and install additional radiation. The normal ventilating areas in shop-type windows and a roof ventilator have failed to produce sufficient circulation of air for the summer months when no fire is in the boiler, with the result that on humid days water will actually run from the pumps and piping so that it is difficult to keep the paint looking presentable. This condition at times extends above the balcony and one summer day became so bad that although the operator removed the recording pressure gauge chart several times during the day to dry it, there is no record of pumping during the night because the paper buckled and held the recording pen away from the chart.

The two other stations have basements only large enough to contain the heaters and coal storage bins. With the exception of the Gulley Run station all basements have caused trouble because of infiltration of ground water. At the Cynwyd station we excavated around the outside of the building and placed a heavy coat of cement mortar on both the outside and inside of the concrete wall. The interior walls were plastered at the other stations.

Although the newer stations have provision for hoisting the equipment built into the walls the older ones did not, and since they contained the heavier machinery, many of our men have suffered from body strains caused by trying to lift or move heavy motors and pumps. Several years ago plans were made to install beams and traveling hoists. We came across a catalogue of a bridge-type hoist made for handling automobiles and rated at a capacity of two tons, which sold for about $125.00. Since none of our individual pieces exceeded this load we purchased one for trial. Shortly afterward we had to dismantle a pump at the Mill Creek station and in order to do this we have to move the motor and all. While no time studies were made to compare actual costs, it is our belief that on this one job alone we saved the most of the hoist in labor time. Needless to say the second hoist was purchased immediately.

The outside of the stations was painted each year or two but the paint was so thinned to make it go a long way that in less than a year the checks and blisters would become so pronounced that it would have to be done over. Painters' torches were purchased and all the old paint was removed from the woodwork by burning and scraping. The wood was given a priming coat; undercoat and enamel were placed on interior surfaces and two coats of lead and oil paint were placed on exterior surfaces. Openings between wood window frames and the brick walls were caulked with oakum and sealed with caulking compound. Steel was placed over windows and doorways where cracks had appeared in the brick walls and the cracks were cemented. The old brick walls were cleaned and painted a light buff color. Floors were cleaned and painted a light gray while pumps, motors and piping were painted black. It does not take long to write it, but many a weary hour was spent by the pumpmen in scouring floors and walls to remove oil and grease which had accumulated for years.

The job has been a big one and although all the spare time of the men has been devoted to it, and by the time it is finished two years will have elapsed since the work was started, but we now have a sound job which will last several years before it will have to be retouched.

Serious and amusing incidents have happened during the work. At one time, acting upon the advice of our paint supply house,

we had sealed the concrete wall in the Gulley Run station dry well with water glass and then applied a coat of recommended paint. The next morning, when the operator entered the plant, he found that the paint had run from the walls and was on the floor. A call to the supply house brought the manager, but since he had never seen anything like it another call brought the chemist from the paint company. He soon saw the trouble, called our attention to a fungus growth on the wall, explained the difficulty in killing it but advised that we try washing the wall with copper sulfate and painting it before the growth could get a foothold. This was during the summer when moisture conditions were bad, so we waited until the next dry day, did as directed, and although the wall has been painted for a year, we have seen only slight traces of regrowth, which we expect to kill with another application of copper sulfate.

Personnel

Schedule of Working Time.—The force operating the stations consists of the assistant superintendent of sanitary drainage and nine pumpmen. Until recently these men had to cover three eight-hour shifts at the Mill Creek station (12-8; 8-4; 4-12), two at the Ardmore station (8-5, day and night), one each at the Cynwyd and Gully Run stations (8-5, day), a total of seven shifts. Each pumpman gets two days and one Saturday and Sunday off per month as well as two weeks' vacation and whatever holidays can be arranged.

In order to give the men advance notice of their Saturday, Sunday and holidays off as well as to show a roughly equal assignment to night and day work at all the stations, an annual schedule is prepared and posted at each station. With seven men required for daily shifts two men are available to work as relief for men off or sick and to cover shifts where the men are on vacations. The most versatile man, a carpenter by trade, is used whenever available from relief work to help with maintenance, while the other relief post is moved among the men at three-month intervals.

Although it is not encouraged, the men are permitted to exchange shifts if they show a justifiable cause, but since the schedule is arranged to have all Saturday, Sunday and holidays off during daytime shifts, the men who exchange shifts must surrender their holidays off during the time that they take a night shift from another man.

This requirement is caused by the loss of the relief man for two days each time he substitutes on a night shift.

In addition to the annual schedule a daily schedule is prepared for each half month showing where each man is each day so that there can be no chance of a misunderstanding.

As this scheduling of the nine men in seven positions could make no allowance for sickness, it is necessary in emergencies to have one man assigned to look after both Cynwyd and Gulley Run stations, where operation was controlled by float switches. Since the men must supply their own transportation the operator would first stop at the station nearer to his home, see that it was operating correctly, do his housekeeping and then go to the more distant station until early afternoon, at which time he would return to the first station until time to leave for the day.

The three shifts at the Mill Creek station were made necessary by the failure of the basin to hold the inflow between the hours of 5 and 8 p.m., but, since the installation and satisfactory operation of the vacuum priming and float switch control, the schedule at this station has been reduced to a day and night shift (8-5). This has eased somewhat the pressure for men and has released another man for general repairs and maintenance for a portion of the time.

Schedule of Operation.—Prior to the adoption of the present organization the men were instructed as to their general duties and then left on their own with a daily visit by the engineer in charge of pumping stations.

When the supervision of the pumping stations was given to the assistant superintendent he prepared a definite program of work which must be done each day. As this varied in minor details at each of the stations, typewritten instructions were posted on each bulletin board and the operator for each shift of the two-week period is held responsible for the fulfillment of his share of the work.

It seems that each operator had a different idea on how the fires to heat the building should be tended and in most cases these ideas violated many of the accepted standards recommended by the heating engineers. Check dampers were not used, fire doors were left open instead, fly ash and soot were not cleaned from the top of the hot water sections and often accumulated to an extent that it was remarkable that the heater gave out any heat. Standard directions were obtained from a local coal dealer, posted with the duties of the operator and the men were informed that the fires must be controlled in this manner. Conditions have improved to a marked degree but it is pretty hard to change a man's system after he has used it forty years.

The men have entered into the spirit of the schedule and after a station has been painted and placed in good condition they are anxious to keep it looking its best.

Selection.—The present operators were drawn from seven trades—three carpenters, one gardener, one taxi driver, one cement finisher, one machinist, one auto mechanic, one electrician. Length of service ranges from 29 years to 7 months with an average service of 14 years.

With the exception of the most recent appointment the men were selected largely upon the recommendation of the commissioner of the district from which the man to be replaced had resided and appointments were based chiefly upon the fact that the new man had a good reputation in the community and needed a job. Anyone could learn to start and stop the pumps, clean the station and keep it warm!

In the case of the last appointment, at the request of the department, consideration was given only to men who had experience with motors, lining shafting, with switchboard work or as a millwright.

The older men are very willing to follow instructions and to help in any way possible but cannot be expected to advance ideas to better operation when they are not familiar with the basic theory. It is true that a large portion of the job is that of a janitor, but the value of the men to the municipality lies in their ability to operate the stations properly, the smallest of which will cost over $10,000, and not only to keep them in condition but to better the operation by improvements as they are developed by the engineers and manufacturers.

To the representatives of the municipalities I want to say—it is not good economy to turn your plant over to that aged policeman or road foreman. He is a good man and needs a job, but poor operation or inexperience will soon cause your equipment to cost you more than the difference between his salary and that of an experienced man.

Designing engineers, you have done your best to create a good plant, but your job is not complete until you place it in competent hands. It is your duty to impress the municipal authorities concerning the vital necessity of good operation.

Operators, it is up to you! Unless you keep your station always at its best, study your equipment to otbain a maximum output for a minimum cost, keep an eye open for modern improvements, learn how and why each unit acts and then show that you know this by timely suggestions or recommendations, you cannot expect to be recognized when that most important day of the year arrives—the day when the annual budget is considered.

Discussion

By J. R. Hoffert
State Department of Health, Harrisburg, Pa.

To give added weight to Mr. Olewiler's comments, let us emphasize the importance of periodic checking of the overall plant efficiency. Payment for power is a principal cost in the operation of a pumping station and it is nearly as continuing as fixed charges. Rising costs for power will probably be quickly noticed by the accounting force—if you have one and it is alert—and yet it may be surprising how long it takes at some plants to discover reduced efficiency, which may be ascribed to increased sewage flows, increased friction in force main, poor power regulation, or unfortunate "demand" charges.

Moving parts do have an unfortunate habit of wearing and increased clearances of wearing rings, a slipping impeller or a broken or bent one, electrical losses, or a variety of defects may markedly reduce operating efficiencies and correspondingly increase costs. And even the best non-clogging pumps do not have a sufficiently high efficiency to waste any of it.

So determine your initial plant efficiency as soon as your plant is well tuned up and thereafter keep that as a goal. When costs rise, track them down by a process of test and elimination until you have localized the trouble. The pocketbook nerve is particularly sensitive.

But checking efficiencies requires that you measure your discharge and this brings up the importance of providing some sort of reliable meter in the original construction of every pumping station. Lacking a meter, preferably of the recording venturi tube, Kennison, nozzle, Parshall flume, or similar non-clogging type, it may be necessary to resort to some type of weir, to a pilot tube traverse of the discharge line, to measuring the rise in the chamber receiving the pump discharge, or even to noting the time required to pump down a sump and estimating the amount of inflow. Actual total head at the center line of the pump, including dynamic suction head, must be determined. This is most conveniently measured by means of a large diameter, carefully calibrated bourdon pressure gage on the discharge line and a similar vacuum gage on the suction line. Power

consumption is best determined by the proper electric instruments but if these are not available, a good approximation can be had by counting the revolutions of the disc of the station meter for a sufficiently long period (with other power-consuming devices temporarily cut off) and applying the proper meter coefficient, which will either be marked on the meter or can be obtained from the power company.

A book might be written upon the testing of efficiencies but a simple method for computing efficiency is given by Homer Beckwith in the 1939 Journal of the Pennsylvania Water Works Operators' Association and in the May, 1940, "Year Book" issue of *Water Works and Sewage*.

Correcting unnecessary consumption of power will pay big dividends and so will the elimination of unnecessarily high base charges. It will seldom be possible to pump principally on "off peak" power but reducing "demand" charges by installing only that rated horsepower actually required; by interlocking motors so that only certain motors can be operated simultaneously; by avoiding unnecessary use of auxiliary power when the main motors are running; and by careful regard for good power factor, will quickly repay any effort on this work.

Good pump packing practice; exclusion of water, sewage, and grit from bearings; proper alignment of parts; a careful choice of lubricants; and a regular schedule for oiling and greasing and renewing oil—all these and many more routine tasks are worth emphasizing again and again. Particularly would we stress the desirability of having a regular scheduled time for each item of maintenance and a card record of it so that no item is not at some time overlooked.

Rigidly supported but self-aligning bearings for long, vertical pump shafts might have been mentioned and reference could have been made to the present practice of using heavy H-beams with their top half filled with concrete, for support of such bearings.

Self-priming pumps do save many a headache for the operator whose pumps have a negative head or "lift" on the suction side. Air cushions which actually keep air out of the force main and pressure relief arrangements to reduce surge pressures in the force main; dependable arrangements to insure that the standby unit will function if the operating unit fails; auxiliary power arrangements, and emergency overflows may prevent what would otherwise be a serious situation.

Some protection against clogging is necessary for all but the larger non-clogging pumps, but screening cutters of the comminutor or triturator types will serve the same purpose and at the same time overcome one of the most vexatious tasks of the operator—the disposal of screenings.

Neatness of plant and grounds is essential—it marks a good operator and helps sustain his morale. Judicious use of paint and cleaning compounds; polished "brightwork" or clean, painted surfaces; rubber floor runners, and well kept switch gear and controls speak for themselves, and attractive grounds appeal to every visitor. Leaking basement walls can cause no end of annoyance and ruin appearances and equipment. However, much can be done to remedy such conditions, even against outside water pressure, by using the best of the fast setting cements or certain waterproofing materials.

But constant maintenance is the crux of good pumping station operation whether it be switchpoints, fuse protection, automatic float control, automatic cutovers or just plain cleanliness. And it can't be emphasized too much that no station is so completely automatic that it does not require systematic maintenance and daily supervision to keep it "automatic."

Which brings us to that most important, most delicate, and at times temperamental part of the pumping station—its operating personnel. Regardless of how hard it may be to attain—even in your state—the goal should be to employ only competent, honest, dependable and versatile men, even at the expense of some "political" disappointments—and then to direct them with tact, fairness and decision.

Mr. Olewiler has had to accept his sewage pumping stations as they came to him with such modifications as time, funds and experience permitted. I would like to carry the operation of sewage pumping stations further back—to the time when the station is only some lines on a drafting board or some thoughts in the mind of the designing engineer—for the design and construction of the station have such a vital effect upon the operation of the station.

Pumping stations—even small ones—are of such varied types and include so many devices, that a volume could easily be written upon the subject. They may be isolated or part of some other building, such as a control house; they may be simple or complicated; completely automatic or manually operated; in nearly continuous operation or operating only intermittently; may use gas, diesel, steam or electrical power; may be large or small factory-fabricated units placed wholly underground; and may vary widely in other respects.

But essentially, so far as effect on operation is concerned, they include the tributary main collecting sewer, a sump of some kind; the room containing the pumps or at least the prime movers, controls, etc.; and the main force.

It may be carrying coals to Newcastle to mention some very obvious things which you gentlemen well know, but I have reviewed many pumping stations and designed some others, and it is surprising at times how often the obvious is overlooked. First, then, a few general remarks about the general design of the station:

It need scarcely be remarked that the site should be appropriate. It should be low enough to receive the sewage from all the area which will be tributary within a reasonable time in the future, with costs of lengthened main collecting sewer and force main and higher pumping head for a lower location balanced against the most of prematurely moving the station farther down the drainage area for a station at a higher location. This need not unduly penalize costs. Smaller pumps may be installed at first, or additional units may be added in the future, or a smaller impeller may be used at first, with some sacrifice in efficiency.

The character of the neighborhood will have a vital bearing upon the station. The station may have to be and can be located in the midst of a closely built up, high grade development, but this usually isn't desirable. But wherever located, the station should be in scale with the surroundings.

It should be architecturally pleasing in appearance. This does not necessarily mean it must be costly, since good appearance is largely a matter of the careful balancing of wall masses and openings and a choice of lines.

The grounds, however large or small, should be attractively planted with trees and shrubs appropriate to the site and of such variety of flowering seasons and habit as will maintain a good appearance for the longest time with the least labor and the least damage from dogs, insect pests and adverse weather conditions.

The station should command attention by its appearance; not attract it by its odor. If you have a very long collecting sewer, have to hold the sewage for too long a period in hot weather, or have poorly designed sumps, perhaps it would be well to consider chlorination at strategic points to control the odors which you must not permit to occur.

Some screening protection of all but large pumps is necessary if the station is to be really automatic. Shredding devices for reducing the clogging solids in sewage can do away with one of the most troublesome features of pumping plant operation. But many plants will continue to use bar screens. Be sure these screens have sufficient area to handle the sewage between inspections; that they aren't so placed that the flow of sewage forces the screenings through them; provide in your design for a proper draining platform and at least sufficient room for the operator's feet when he's cleaning the screen; and a self-draining screening receptacle. Make the screen chamber or pit decently accessible and provide means to lift out the screenings can. Don't ask any self-respecting operator to lug a G.I. can of wet screenings up a long set of ladder rungs and then shove the can through a glorified manhole. Neither is it necessary to provide a ship's crane to remove the screenings. An overflow channel to bypass the screen is a very useful device. And an emergency sump overflow—used for emergency only and where there is no real menace to health—can be a very ready help in time of trouble—even if it must be sealed by the state health department—and may prevent what might otherwise be a very serious situation.

Wherever practicable, divide the sewage sump in two parts interconnected by gates of some sort—it certainly will be useful in case of repairs or cleaning. Give adequate slope to the floor of the sump to prevent stranding of solids and terminate the pump suctions in a low point of the sump in such a manner that the pumps will not lose their suction until the sump is practically empty. Also, provide convenient facilities for flushing the sump and screen chamber. And put the float controls where they won't be undesirably affected by pump action.

Let the building be sufficiently ample in size to make all the equipment conveniently accessible. It may cost a little more in the beginning but it pays large operating dividends. If an operator has to crawl over equipment while watching that his coat tail doesn't catch in some rotating part or that he doesn't make some electrical contact; or if he has to solve a problem in geometry each time that he tears down a pump or breaks a pipeline—well, maybe he just won't do it soon enough the next time.

Pump controls and switch gear conveniently arranged around

or near the walls of the room with the pumps and motors out in the room with ample space around them, and piping in trenches or so disposed above the floor as not to be a trap for the unwary, do much to help operation and improve appearance.

And let there be at least a washbowl and in larger stations a toilet and perhaps a shower and locker room for the operator. And at least a small shelf or desk for making out reports, keeping records, etc. A suitable cupboard to keep equipment which might otherwise litter up a corner, and a well kept tool board will make for convenience and good appearance. Ample window area for light and ventilation should be provided. Steel sash is added protection against vandalism.

We just mentioned ventilation but it is surprising how many otherwise well designed pumping stations are so deficient in good ventilation. The penalty is either stuffiness and possible danger from gases, or, more generally, sweating walls, dripping, rusting equipment, scaling paint and wet floors.

Wherever possible there should be complete separation between the wet and dry wells or the operating floor. A roof ventilator with a damper is desirable but provision should be made to insure a good circulation of air in the dry well and in all inside rooms or compartments and to insure venting of the wet well.

In some cases all that is necessary is to carry a duct to a point near the floor of the dry well and to rely on stairway openings or floor gratings to provide circulation. One large power company has very successfully ventilated its underground structures by merely carrying two small pipes from the same level in the spit to a point some distance up the side of an adjacent outside pole with the one pipe carried a little higher than the other. This slight difference provides a continuous gravity circulation of air which keeps the pits dry. However, positive ventilation by fans is so simple and so inexpensive that it is increasingly the best answer. But by whatever means, get good ventilation.

Also, provide a sump pump or at least a small valved line on the suction of the main pumps and carry it to a shallow sump in the floor so that water on the floor may be effectively removed.

Thus far we have said very little about what you may consider the heart of the whole station—the pumps and their motors. Well, since the designer does consider them so important, they usually do receive much careful consideration. And they cover such a very wide field that they are a subject in themselves. Even so, there may be some room for comments about them here.

The pumps themselves are nowadays nearly always centrifugals. Fortunately for the operator, the open shaft vertical pump in the wet well is not used so much any more. Even the enclosed shaft motor in the wet well offers him enough trouble.

A dry well increases the size of the station but it certainly is a boom to the operator and wherever practicable should be provided, whether the pumps are vertical or horizontal.

Quick opening handholes for cleaning pumps, replaceable shaft sleeves and wearing rings, water deflectors, pressure water seals, drip piping, direct connection through flexible couplings to the prime movers—are all highly desirable. Shafting should be as short as possible.

The pumping capacity should be adequate and in duplicate for all normal requirements. If pumping is to be direct to a sewage treatment works, there will be less disturbance to the treatment processes if the pumping can be done by increments in pump capacity and sufficient sump capacity can be provided to permit the pumping to somewhat approximate sewage flows or help smooth out sudden peaks. This should, however, not induce too ready adoption of unduly small step changes by variable speed motors which carry their own troubles.

Wherever possible, the pumps should be so placed that they will have a positive head upon their suction lines and thus be self-priming, otherwise an automatic priming device should be provided so as to do away with troublesome foot valves.

In order that each pump shall carry its own share of the load, each should be provided with a suction line direct to the sump but these should be interconnected by a manifold properly valved. The discharge piping should be carefully designed to meet its hydraulic requirements.

Again we would emphasize the desirability of providing, at the time the plant is constructed, a suitable means for measuring the discharge of the pumps.

Adequate standby power is essential in direct proportion to the seriousness of power failure. Connections to more than one public utility, an emergency generator, gasoline power, or whatever is most practicable and necessary, should be provided.

It would be possible to consider so many other features but this discussion has already exceeded its proper proportions—like the assisting minister who preaches his sermon when offering the prayer. But we cannot close without one final word. Don't make, permit, or continue any connection between a potable water supply and any sewage handling device or pipe lines. If a float tube or meter is to be kept free of sewage solids by means of a small flow of clean water, see that it enters it from overhead by gravity through an air gap. If a venturi ring or some other device is to be flushed out by water pressure, see that the connection is only a temporary one which must be held in position by the operator while using it—and then don't permit it to be wired or clamped permanently in position. Be sure water seals are supplied from tanks supplied in turn by water entering over the top of the tank through an air gap, or use a water seal pump taking its supply from such a tank. Remember there's only one safe rule—don't permit any cross connection. The wholly improbable or the "impossible" has actually happened too often to take any chances.

PACKING POINTERS

The following suggestions and warnings, based on the many years of practical experience of a prominent eastern packing manufacturer, will be found valuable in the installation of packings. To follow them may mean freedom from trouble that would occur when even the best packing is improperly installed.

1. NEVER fail to make clear to the manufacturer what the packing is to pack. In other words, with what will the packing make contact?
2. NEVER guess at a size, diameter, width, or height, when ordering packing. Many failures result from small errors in dimensions.
3. NEVER allow too little or too much clearance between follower plate and inside cup wall, or any metal parts behind any upright leather wall. Clearances of 1/16" to 3/32" on each side, depending on size of packing, is recommended.
4. NEVER doctor packing lips with a pocket knife or file, or batter lip in installing. A rounded lip destroys the seal. Packings can be softened by soaking in warm water if necessary.
5. NEVER apply cup packings with flange too high for clearance at the head of the cylinder. Keep systems clean, so sediment will not collect in cylinders and wear the packing.
6. NEVER apply cup packings to end of badly worn plungers; pressure will force the packing down into clearance between plunger and cylinder. Leather washers cut from old cup packings can be made to reline such equipment to proper dimensions.
7. NEVER apply "U" packings where plungers are worn without reinforcing under the heel with leather cushion rings.
8. NEVER look for long service on scored plungers or in scored cylinders; resurface or reline such equipment to proper dimensions.
9. NEVER allow water to corrode cylinder walls, plungers, stems or rods. Use an anti-rust agent that will prevent this and will act as a lubricant.
10. NEVER squeeze hemp or fabric filled "U" packings in glands where such packings are to replace solid section compression packings; set gland up to point where "U" packings are free to function properly.

DESIGN OF AIR DISTRIBUTION SYSTEMS FOR ACTIVATED SLUDGE PLANTS

By HENRY R. KING
Senior Civil Engineer
The Sanitary District of Chicago

THIS article discusses the pressure losses in the flow of air and their consideration in the design of an air distribution system for an activated sludge plant. The principles of design are applicable in determining the layout for any air distribution system, regardless of the arrangement of the diffusers in the aeration tanks. This discussion, however, is confined to the air piping and diffusers for a plant employing spiral flow aeration tanks which are now almost universally used.

A major expense in operating an activated sludge plant is for providing compressed air. Over a period of from two to five years such cost usually exceeds the first cost of the entire air system. The pressure losses in the piping and diffusers ordinarily cause from 10 to 20 per cent of the cost of the air and, in extreme cases, as much as 35 per cent where the diffusers are relatively close to the surface of the mixed liquor in the aeration tanks. Herein is discussed the determination of the optimum relationship between the annual costs of the pressure losses in the flow and the diffusion of the air, and the annual fixed and maintenance charges for the air piping and diffusion system.

General Layout of Piping and Diffusers

The effective use of compressed air is highly important because of the expense involved. Therefore efficient distribution and diffusion must be sought. Of the several types of diffusers those most commonly used are the porous plates installed in containers aligned in rows at the bottoms and along the sides of the aerated channels of the tanks. The diffuser plates can be manufactured of such close uniformity that when carefully set to the same elevation, a number of inter-connected containers may be supplied from the same air connection without any appreciable unevenness in the rate of diffusion over the entire group of plates. At the Calumet Sewage Treatment Works of The Sanitary District of Chicago, 72 plates per air connection operate satisfactorily. The rows of diffusers should be divided into enough groups each with a regulating valve, so that the rate of diffusion of the air along a tank may be effectively controlled. An indicating, recording and integrating meter in the air main to each battery and an indicating meter and regulating valve in each of the headers to the tanks and channels will provide records of air use and the means for maintaining the proper division of the air to the various units. In a diagrammatic sketch (Fig. 1) is shown the customary location of meters and regulating valves for an air system.

Diffusers

In diffusing air in aeration tanks the effect of the number of rows of diffusers has been studied. In the Sanitary District, two aeration tanks, treating the same mixed liquor, were operated in parallel on identical detention periods and at equal air rates per gallon of sewage. Comparative tests, with one tank operating with more rows than the other, indicated that one to four rows were not appreciably different in efficiency. However, the conclusion should not be drawn that one row of diffusers is sufficient for all practical widths and depths of the aeration channel, for there is an economic limit to which the diffuser area can be reduced lest the pressure losses for diffusion become excessive. Therefore some consideration should be given to the losses occurring in this part of the system.

Modern diffuser plates are generally made of either silicon dioxide (silica) or aluminum oxide grains cemented into a porous mass by a ceramic binder, then pressed, dried and burned. In recent years the trend has been toward the use of larger grains and less thickness of the diffusers (plates or tubes) in order to reduce the pressure losses. A. J. Beck* has shown that diffuser plates of large grain size produce slightly lower bubble surface area per unit of air. Tests made at the Southwest Sewage Treatment Works of the Sanitary District in aeration tanks with channels 32 ft. 9 in. wide by 15 ft. 6 in. water depth indicated that, for the same degree of sewage treatment, plates of larger grain size (one row of 80-permeability plates in service about one year) required 15 to 20 per cent more air than plates of smaller grain size (two rows of 40-permeability plates in service about four years).

*Sewage Works Journal, January, 1936.

Permeability Ratings

To assume uniformity, diffusers are specified and installed according to a "permeability rating." Such rating is expressed as the number of cubic feet of free air per minute at 70 deg. Fahr. and 10 to 25 per cent relative humidity which will pass through one square foot of diffuser area, to atmosphere, with a pressure loss equivalent to 2 inches of water when the diffuser is tested dry at 70 deg. Fahr. The diffuser plates now in use vary in permeability from about 10 (if installed some years ago) up to from 30 to 80 in some plants recently constructed.

Causes of Pressure Losses

The pressure loss occurring in dry plates during the permeability rating test is due entirely to the viscous flow of the air through the small internal passages. When such plates diffuse air into water, a pressure loss occurs besides that attributable to viscous flow, probably due to the capillary force of the surface tension of the bubbles formed in the water at the upper surfaces of the plates. When diffusing air into the mixed liquor in aeration tanks, the pressure losses are much greater than occur when the plates are tested clean and dry. Figure 2 illustrates the general manner in which pressure losses for diffuser plates ordinarily tend to progressively increase after installation in aeration tanks. No scales are given, however, because such losses differ for different sewage treatment plants.

The capillary force increases rapidly after the diffusers are put into service, but usually reaches a maximum in less than a year. This force varies inversely as the diameter of the openings on the discharge *surface* of the diffusers. An increase, therefore, indicates that a surface clogging or coating has reduced the size of these openings. Evidently a limit is reached to which the size of openings can be reduced before the increased velocity resulting therefrom becomes great enough to prevent further reduction, and thus limits the extent of this particular loss. The surface clogging materials are primarily biological growths or, in some instances, deposits from chemical reactions between the air and substances in solution and, also, dust particles filtered from the air. The character of the clogging materials therefore depends primarily on the nature of the sewage being treated, and the loss due to capillary force depends upon the nature of the clogging materials and the rate at which the diffusers are operated.

When the air is reasonably clean the loss of pressure caused by the viscous flow of the air through a diffuser continually increases as a result of the progressive thickening of the surface clogging. Since, for this type of flow, the loss at a given rate varies inversely as the fourth power of the diameter of the passages, it is apparent that a very thin coating or shallow depth of surface clogging with relatively small openings, but equal in number to the passages through the diffusers, would account for the major part of the pressure loss caused by the viscous flow of air.

After a period of service, representative diffuser plates in the Chicago plants were broken to reveal their internal condition. With the exception of diffuser plates operated on unusually dirty air all the clogging was found at and just below the upper surfaces. A partial closure of the upper ends of the internal passages usually occurs within the first year of operation. This tends to retain near the top surfaces of the plates part of the particles carried up by the air through the clean portion of the passages. As such particles gradually accumulate and the depth of clogging increases from deposits and biological growths, the pressure loss attributable to the viscous flow of the air progressively increases. Filtering of the air supply should remove most of the substances likely to cause plate clogging. However, a small amount of dust usually remains in the air and additional small particles, such as scales from internal coatings and corrosion products, may be picked up from the distribution piping by the air stream.

Pressure Loss Formula Developed

Where operating conditions remain substantially uniform, pressure losses for 12 inch square diffuser plates, after the capillary loss has reached a constant value, may be expressed approximately by the formula:

$L = C + YVR$, in which,

L = pressure loss (inches of water)
C = capillary force (inches of water)
V = annual increase in viscous flow loss per cu. ft. per min. free air (inches of water)
R = rate of flow per plate (cu. ft. per min. free air)
Y = years in service

Approximate values for the formula were obtained from tests in plants of the Sanitary District, under normal operating conditions as follows:

Permeability Rating	Service Prior to Test: Years	Service Prior to Test: Rate Cu. Ft. per Min. (Free Air)	C Inches Water	V Inches Water
11	5.5	1.5 to 2.5	7	2.1
16	5.5	0.5 to 1.5	6	1.2
40	1.3	0.5 to 1.5	6	1.1
65	0.8	0.5 to 1.5	6	0.9
40	2.0	2.5 to 3.5	2	6.0
80	1.0	6.0 to 7.0	1	3.0

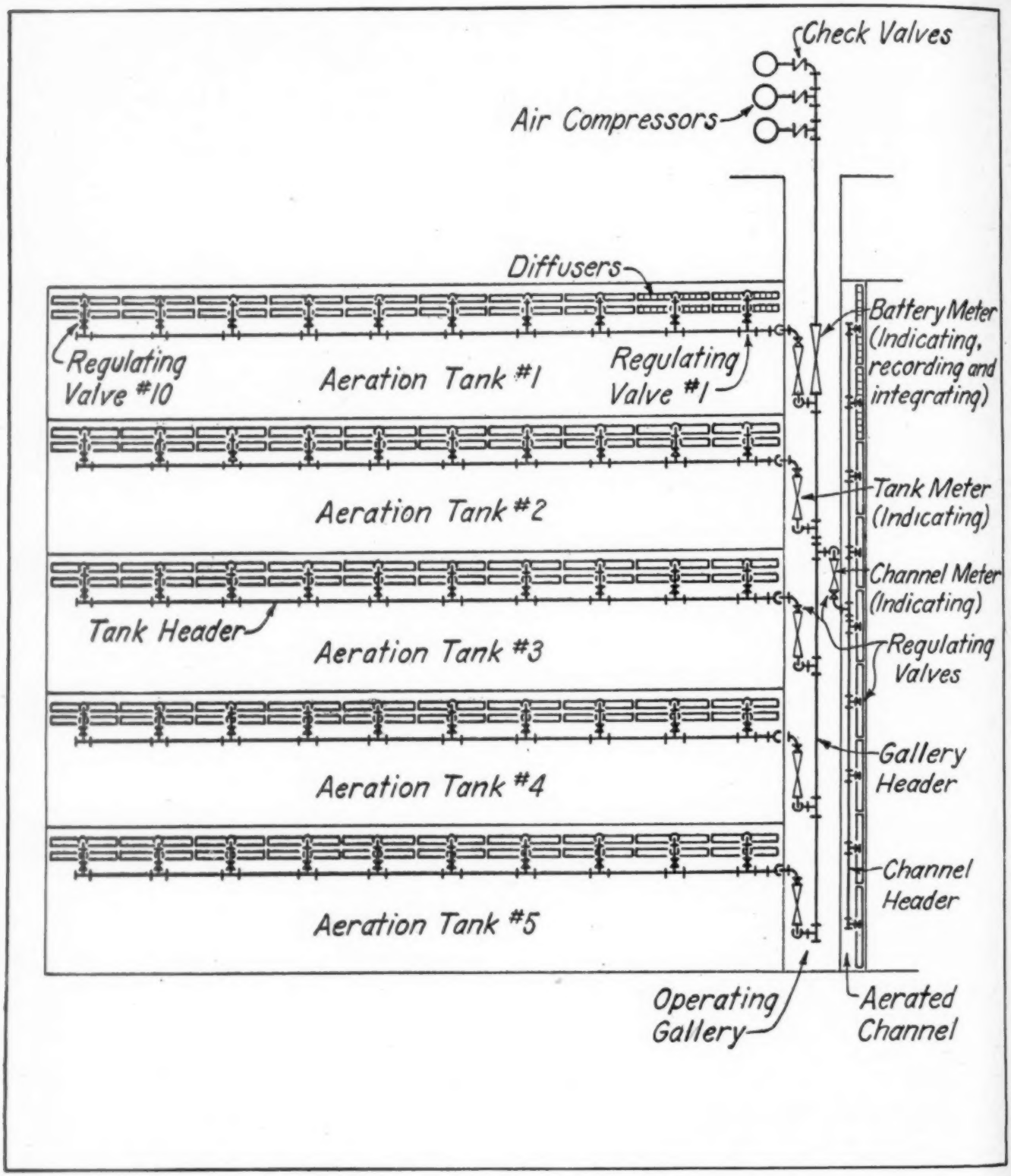


Fig. 1.—Illustrative Sketch of Typical Air Distribution System of Modern Activated Sludge Plant
(Showing locations of meters and regulatory valves to diffusers.)

The plates referred to in the above table were used only on filtered air. The entire piping system which served the plates with 11 permeability was badly rusted internally. Very little or no rusting was found in the piping supplying the other plates.

In the case of the last two plates (40 and 80-permeability) considerable dirt passed through the filters due to the unusual amount of dust and smoke in the air in the vicinity of the sewage treatment works. Therefore these plates were an exception to the general rule. Clogging took place on the underside. The low values of C indicate less than normal surface clogging. A test, previously mentioned, indicated the 40-permeability to be more efficient than the 80-permeability plates probably true because of more surface clogging on the former.

Some rather high losses, both capillary and viscous, are omitted from the above tabulation. These resulted with the 40-permeability plates at the Calumet Sewage Treatment Works and was traced to deposits of ferric oxide in the surface of the plates, abnormal content of ferrous iron in the sewage being the source of the trouble.

At times during spring and summer, humid air causes condensation in the diffuser plates. Pressure losses then rise above normal.

Based on the probable pressure losses during the life of a plant, assuming periodic cleanings of the diffusers, annual costs may be approximated and the number of rows of diffusers determined. The probable pressure losses may vary with different sewages. But little data exists on the effects of the different average operating rates per plate. In the writer's opinion, fewer rows mean greater losses but with smaller values for the C and V factors in the pressure loss formula.

Plate Cleaning

Plate containers should be made of material unlikely to deteriorate or release particles to clog the diffusers. However, cost largely governs the selection of the type of container with consideration for the method* and expense of plate cleaning. The Sanitary District uses pre-cast concrete container boxes into which the plates are set with a lean cement mortar. When necessary the plates are usually cleaned with acid applied on the surface with plates in place. This effects a reduction of from 60 to 70% in the viscous flow loss. Tests made a few months after cleaning showed no reduction in the capillary pressure loss.

FIGURE 2

PRESSURE LOSSES FOR
DIFFUSER PLATES IN AERATION TANKS
(Illustratative)

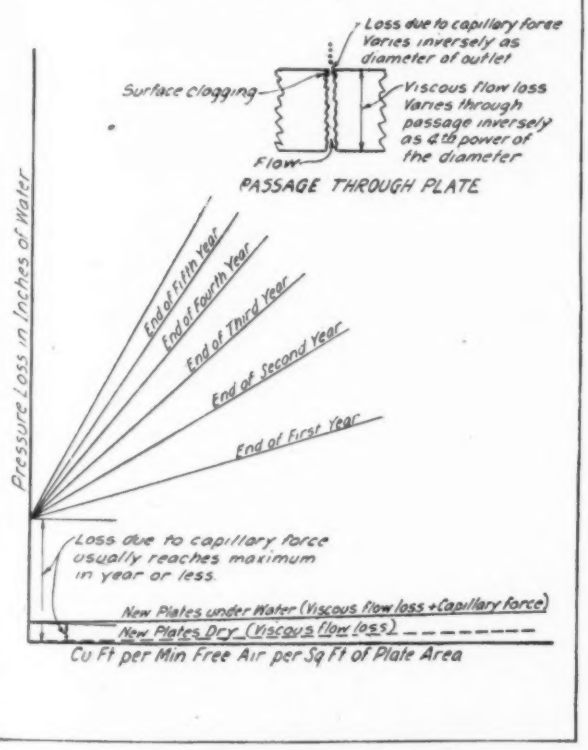

Loss due to capillary force Varies inversely as diameter of outlet
Surface clogging
Viscous flow loss Varies through passage inversely as 4th power of the diameter
Flow
PASSAGE THROUGH PLATE
Pressure Loss in Inches of Water
End of Fifth Year
End of Fourth Year
End of Third Year
End of Second Year
End of First Year
Loss due to capillary force usually reaches maximum in year or less.
New Plates under Water (Viscous flow loss + Capillary force)
New Plates Dry (Viscous flow loss)
Cu Ft per Min Free Air per Sq Ft of Plate Area

Fig. 2.—Graph Illustrative of Progressive Build-up of Pressure Losses Through Diffuser Plates

Surface application of acid is not so effective when plates clog on the underside.

Frequent cleaning in place by means of acid weakens the cement mortar. Consequently some of plates blow out. For that reason air headers should be above the liquid level in the tanks to prevent sludge entering the air system and spreading to the underside of other plates. Fixed plates are not entirely satisfactory. Concrete container boxes at the North Side Sewage Treatment Works are showing signs of disintegration after 15 years of service. The Sanitary District is experimenting to improve containers and plate setting for cleaning in place and also on the use of cast iron container boxes from which plates are easily removed for separate cleaning.

Frequency of Cleaning

How long a plant may be operated before it becomes economical to clean the diffusers depends on their life, operating and clogging rates, and the cleaning cost balanced against expected power cost reduction. The North Side Sewage Treatment Works with 16-permeability plates was operated 12 years without diffuser cleaning. Then cleaning was done only on the groups of plates where the pressure losses were greatest. The Calumet Sewage Treatment Works Extension required cleaning of the plates after less than a year of operation because of ferrous iron (steel mill waste) in the sewage produced ferric hydrate clogging on the surface of the plates. The steel mill wastes in the sewage have been reduced considerably but it is still necessary to clean diffusers about once a year. At the Southwest Sewage Treatment Works due to an excessive amount of dirt in the filtered air, the plates clogged so rapidly on the underside that cleaning was required after two years of service. Surface aciding has not been effective. Tanks are dewatered and the plates blown out with dry air. End plates are then removed and the containers blown out with a mixture of air and water. Improvements in air filtering will be made after the war. On the other hand, the Calumet Sewage Treatment Works, put in service several years ago, required cleaning of the plates after less than a year of operation because the ferrous iron (steel mill waste) in the sewage produced ferric hydrate clogging of the plates.

The Sanitary District experience indicates that diffusers in aerated channels for return sludge (8000 to 20,000 p.p.m. solids) clog more rapidly than those used in aeration tanks or channels for mixed liquor carrying 1000 to 3500 p.p.m. solids. In consequence, the return sludge channels should have a lesser water depth than the aeration tanks to compensate for the greater friction losses likely to occur in the diffusers. Diffuser plates, if possible, should be kept in continuous service, because pressure losses are increased by shut down for periods.

Distribution Piping

More expensive in first cost than the diffusers and containers is the air piping system. For use in its design the writer prefers the Fritzsche air formula. It resembles formulae for the turbulent flow of water in pipes except for a modification to take care of the effect of the variation of viscosity with temperature, which is relatively important in connection with the flow of air. The Fritzsche formula is as follows:

$$\Delta P = \frac{1.268}{10^6} \cdot \frac{T}{P} \cdot \frac{Q^{1.825}}{d^{4.973}}, \text{ in which,}$$

ΔP = drop in pressure per ft. of pipe, in lb. per sq. in.
P = mean absolute pressure* of flowing air, in lb. per sq. in.
*(Gauge + atmospheric)
T = mean absolute temperature of flowing air (460 + temperature, Fahr.)
D = diameter of pipe in inches.
Q = discharge in cu. ft. per min. of free dry air at 60 deg. Fahr. and 14.7 lb. per sq. in. atmospheric pressure.

Friction Losses Observed

The pressure losses in air mains in the Sanitary District Works were determined to check the Fritzsche formula with the following result:

Pipe	Observed Loss in Per Cent of Formula Loss
4-in. galv. steel	105
10-in. cast iron	120
24-in. cast iron	120
60-in. cast iron	103

*See "Diffuser Servicing" by F. C. Roe, Water Works & Sewerage, April 1934. (Also reprinted in Reference and Data Issue of May 1939.)

The first three pipes handled warm moist air and, although in service less than two years, their inner surfaces were probably somewhat corroded. This assumption is based on the fact that after 10 years of service they were found to be badly rusted. Apparently at the time of the test the interior surface was in better condition for the 4-inch galvanized steel than for the 10 and 24-inch ordinary tar coated cast iron pipes. The air flowing in the 60-inch cast iron pipe was warm and dry. This pipe was tested after three years' service and was found in as good condition as when first installed. The tests indicated that the Fritzsche formula applies to pipe of a roughness equivalent to a value of about C = 140 as the roughness or capacity coefficient in the Hazen-Williams formula for the flow of water in pipes. Applying this coefficient to the Fritzsche formula with a base value of 140 for the original form,

$$\text{the formula becomes } \Delta P = \frac{0.01196}{C^{1.852}} \frac{T}{P} \frac{Q^{1.852}}{d^{4.973}} \text{ in}$$

which C is the Hazen-Williams coefficient. This indicates values of the coefficient for the pipes tested at 136 for the 4-inch, 127 for the 10-inch and 24-inch, and 138 for the 60-inch pipe.

Pipe Roughness

With the types of compressors (centrifugal and positive) ordinarily used, the compression is nearly adiabatic. The result is a temperature rise of as much as 80 deg. Fahr. in air compressed for aeration tanks of from 10 to 15 foot depth. As the air leaves the compressors it contains the original content of atmospheric moisture but the relative humidity is low because of the increased temperature. In conveying such air, rusting will vary in different parts of the system.

In the large mains and branch pipe lines inside the operating galleries the air is still too warm for the dew-point to be reached and condensation to occur. Such piping, once in continuous service, needs no protection on its interior surfaces. During the construction period, however, this piping should be protected with a suitable coating.

Moisture occurs in tank and channel headers when submerged in the mixed liquor, or when exposed to the weather. As the air cools during travel condensation results, particularly when the atmospheric (intake air) has a high relative humidity and is warmer than the sewage. In time the protective coatings on the interior of these pipes may be affected. Hence, where rusting of headers internally may be a potentiality, the coefficient of roughness should be selected to represent the interior surface condition that will actually obtain over a period of years.

Condensate traps were installed on the submerged headers in the aeration of the North Side Sewage Treatment Works. These traps, however, were not found to be necessary and are not now in use. There was, however, corrosion in the extremities of the headers after several years of operation.

Losses Caused by Valves, Fittings and Meters

Pressure losses result from the disturbances in flow caused by fittings, valves and meters. For flow through pipe the loss of head at a fitting is the same for air as for water, if measured in each case as a column of the particular fluid. Therefore, test data on the flow of water in pipes may be utilized for air. For example, assume air weighing 0.1 lb. per cu. ft. flowing at a velocity of 40 feet per second. A fitting that causes for water a loss of 0.5 velocity head would cause for air

$$0.5 \left(\frac{V^2}{2g}\right) = 0.5 \left(\frac{40 \times 40}{64.4}\right) = 12.5 \text{ feet of air} = \frac{12.5 \times 0.1}{144} =$$

0.00868 lb. per sq. in. pressure.

A fitting loss results from the disturbance it causes in the normal flow. Because of a viscosity difference the friction head loss for air supplied to aeration tanks, expressed as a column of fluid, is about 40% more than that of water. Therefore, experimental results on water which include a combination of disturbed flow and friction loss, as for example the overall loss in a Venturi meter tube, should be increased when applied to air. The losses in check valves depends on the weight and balancing of the moving parts and are determined by computing the pressure drop at the valve that will hold the moving parts in position to provide a sufficient opening to pass the required flow.

Economical Pipe Sizing

Where the total annual fixed and maintenance costs for a pipe line varies approximately with the weight, a formula for economical size can be derived. In general, whatever the pipe material, practical minimum wall thicknesses should be used that will result in pipes that can be manufactured, handled and installed satisfactorily. In an activated sludge plant the stress in the wall of a pipe due to the air pressure is not a determining factor. Cast iron pipe may be of the lightest class. For steel pipe, by logarithmic plotting of the weights of pipe of the minimum wall thicknesses recommended for installation, the formula is derived, $W^* = 0.33\ d^{1.635}$ in which (W) is the weight in pounds per foot and (d) the diameter in inches. The weight of material for couplings and flanges is not included. The formula is applicable only where an air main is in long sections and the joint material is a relatively small part of the total weight, such as is represented by an air main from the compressors to the gallery of the aeration tanks. The formula for the economical size is derived as follows:

A = annual cost per cu. ft. per min. free air per lb. sq. in. pressure (Gauge)
B = annual cost per lb. of pipe (interest, depreciation, and maintenance)
C = annual power cost per foot of pipe
D = annual interest, depreciation and maintenance cost per foot of pipe

$$C = A\,Q \frac{0.01196}{C^{1.852}} \frac{T}{P} \frac{Q^{1.852}}{d^{4.973}} \text{ (From modified Fritzsche formula)}$$

$$D = B\,(0.33\,d^{1.635}) \qquad \text{(For steel pipe)}$$

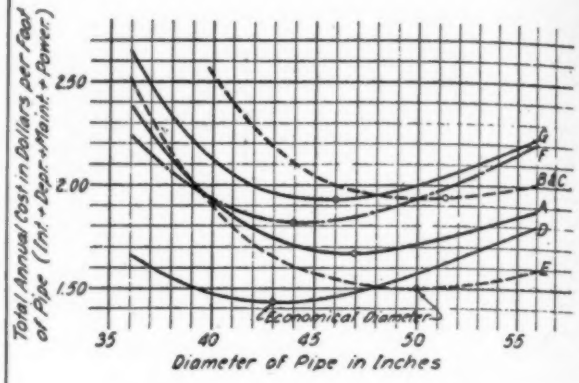
$$C + D = A \frac{0.01196}{C^{1.852}} \frac{T}{P} \frac{Q^{2.852}}{d^{4.972}} + B\,0.33 d^{1.635}$$

(Total annual cost)

FIGURE 3

ANNUAL COST PER FOOT OF STEEL PIPE OF PRACTICAL MINIMUM WALL THICKNESS

Air Flowing at Temperature of 125 Deg. Fahr and Pressure of 22.0 Lb. per Sq. In. Abs.



CURVE	Air in Cu. Ft. Min. 60 Deg. Fahr. 14.7 Lb. per Sq. In. Abs. (Q)	Pipe Coefficient H & W "C"	Annual Costs (A) Power per Cu. Ft. of Air per Lb. Sq. In. Pressure	Annual Costs (B) Int. Depr. Maint. per Lb. Pipe
A	40,000	140	$0.20	$0.0072
B	48,000	140	0.20	0.0072
C	40,000	105	0.20	0.0072
D	32,000	140	0.20	0.0072
E	40,000	140	0.24	0.0058
F	40,000	140	0.16	0.0086
G	40,000	140	0.20	0.0086

Fig. 3.—Economical Pipe Diameter Curves Relationship of Total Annual Capital and Power Costs to Pipe Sizes in Air Systems. (For formula derivation and method of computations see text.)

*In some instances in the Sanitary District work large steel pipe is installed a small percentage heavier than this formula would indicate.

When $C + D$ is a minimum $\frac{d(C+D)}{dd} = O$

$$O = -0.00595\, A \frac{T}{P} \frac{Q^{2.852}}{C^{1.852}\, d^{5.973}} + 0.54\, Bd^{0.635}$$

$$d^{6.608} = 0.1102 \frac{A}{B} \frac{T}{P} \frac{Q^{2.852}}{C^{1.852}}$$

$$d_e = \frac{0.716}{C^{0.28}} \left(\frac{A}{B}\right)^{0.151} \left(\frac{T}{P}\right)^{0.151} Q^{0.432} \quad \text{(Economical diameter)}$$

For Cast-Iron Pipes

For Class A bell and spigot cast iron pipe of standard 12-foot lengths of which the weight per foot is expressed by the formula, $W = 11 + 0.85\, d^{1.717}$, the economical diameter is:

$$d_e = \frac{0.618}{C^{0.287}} \left(\frac{A}{B}\right)^{0.149} \left(\frac{T}{P}\right)^{0.149} Q^{.426}$$

For Steel Pipes

The total annual costs per foot of steel pipe of various diameters, with a practical minimum wall thickness, are shown in Fig. 3 for several different sets of conditions covering flow, pipe roughness and costs for power, interest, depreciation and maintenance. This diagram indicates that the total annual cost of the pipe varies but slightly for a 10% range in size above and below the most economical diameter. Therefore, a standard size pipe nearest to that computed as the most economical should be used. The size of pipe most economical for the set of conditions of Curve A is within the ranges of relatively economical sizes for the sets of conditions of the other curves. The values of the factors affecting the total annual cost are the same for the other curves as for Curve A, with one or two exceptions, in each case, which differ by approximately 20%. A piping system may be relatively economical even though operating under conditions differing from those used as a basis for its design.

Importance of Friction Coefficients

Curves C and G (Fig. 3) indicate that for a flow of 40,000 cu. ft. per min. the total annual costs are the same for a 46-inch pipe with a roughness coefficient of 140 and a 52-inch pipe with a coefficient of 105, when the interest, depreciation and maintenance charge per pound on the former is 120% of that for the latter. The pipe sizes are the most economical for the two sets of conditions of curves C and G. Pipes of different degrees of roughness should be compared on the basis of the total annual costs for the most economical sizes.

The average weight per foot of some parts of the air piping system cannot be expressed by formula. For instance, a header may include fittings, odd lengths of pipe, various types of connections, and the pipe and fittings may be of different materials. To meet such conditions, the sizes may be determined on the basis of cast iron or steel pipe, using the above economical formulae and then adjusting the sizes to the average annual cost of the pipe under consideration. For 16-inch and smaller diameter no size adjustment should be necessary since a 50% difference in annual cost per foot (by the formula) only means a 6% difference in diameter. Usually the sizes can be determined on the annual costs of installed straight pipe alone. Although fittings are more expensive on a footage basis, they disturb the flow and cause much higher pressure losses per foot which tend to compensate for their higher costs insofar as size selection is concerned. Since the diameter of a pipe can be varied somewhat when near the economical size, with practically no change (Fig. 3) in its total annual cost, the formulae are accurate enough as a practical method of computing pipe sizes.

Application of Formulae

These formulae are convenient for the initial layout of an air piping system. The sizes should be checked afterwards arithmetically by comparison with the total annual costs of piping of diameters of one size larger and smaller. Such a comparison should include any costs chargeable to piping such as a service tunnel, when its size must be determined by the diameter of an air main. Generally, however, no revision of the sizes calculated by formulae will be found necessary.

Where a piping system is to provide for the uniform distribution and diffusion of the air into the mixed liquor in the aeration tanks, the *pressure loss to the most remote diffuser determines the pressure at the compressors* (Fig. 1).

Cost of Throttling

Theoretically, the throttling of regulating valves is necessary in the connections to the plate containers and in the headers to the tanks, except for the most remote, in order to properly control the distribution of the air. This throttling affects the determination of the economical diameter. For instance, the loss of pressure per foot occurring at any point along a header applies to the total flow entering the header, since that part of the flow already diverted must be throttled at the regulating valves, thus introducing an equivalent loss at those points. Therefore in using the economical formula, the cost per cu. ft. per min. of air to be used for any location along a header, relative to the average cost for the plant, should be proportionally larger as the ratio of flow entering the header is to the flow at the point under consideration. For example, take a case in which air can be compressed for $0.20 per cu. ft. per min. free air per year per lb. sq. in. of pressure. Assume that the size of the gallery main (Fig. 1) is to be determined between the points where tank headers No. 3 and No. 4 branch off. For the value of (A) in the economical formula a cost for air of 5/2 x $0.20 = $0.50 instead of $0.20 should be used, since theoretically the flow to the first three tanks must be throttled enough to force two-fifths of the flow to the last two tanks thus causing a loss of pressure for the entire flow equal to that occurring in the length of main under consideration. This procedure in design results in low velocities in the extremities of the headers with a partial conversion of the kinetic into static energy, and produces rather flat pressure gradients. For a gallery header laid out in this way the pressure drop is so slight that the pressure head at the entrances to all the tank headers is almost the same and, therefore, all the tank headers should be the same size. Then, theoretically, very little throttling will be required at the inlet valves to these lines.

Theoretically, a piping system can be laid out so that no throttling of valves will be required. In such a layout the closer a part of a system is to the compressors the smaller should be the pipe size used for a tank header or plate connection. The object to be obtained by the right selection of pipe sizes would be an equal pressure loss to all the plate containers in the aeration tanks when all valves are fully open. Practically, however, difficulties would be encountered in attempting to provide a layout of this kind, inasmuch as pipe of standard sizes must be used which probably would not conform in sizes to those as computed in all cases. Also, from the standpoint of construction and maintenance it is not desirable to have a variety of sizes of piping and valves for the various tanks, which a layout of this kind would involve. Actually the diffuser losses are not the same for all tanks, due to the variations which are bound to occur in the operation of the units of a battery. Therefore, similar piping layouts for all the tanks seem warranted since in general the throttling of tank regulating valves will be only that required to force air to whatever tank happens to have the greater diffuser losses at any particular time during the operation of a plant.

The procedure to be followed in determining the layout for an air distribution system, as discussed in this article, is that developed by and generally used in the Sanitary District of Chicago, where relatively large activated sludge plants have been constructed. The principles of design presented, however, should apply equally as well to smaller plants.

Although the discussion has been confined to the uniform distribution of air in aeration tanks the factors involved are fundamentally the same where a piping system is required for "tapered" or other non-uniform distribution of the air.

CHICAGO PUMP COMPANY

2349 Wolfram St., CHICAGO, ILLINOIS

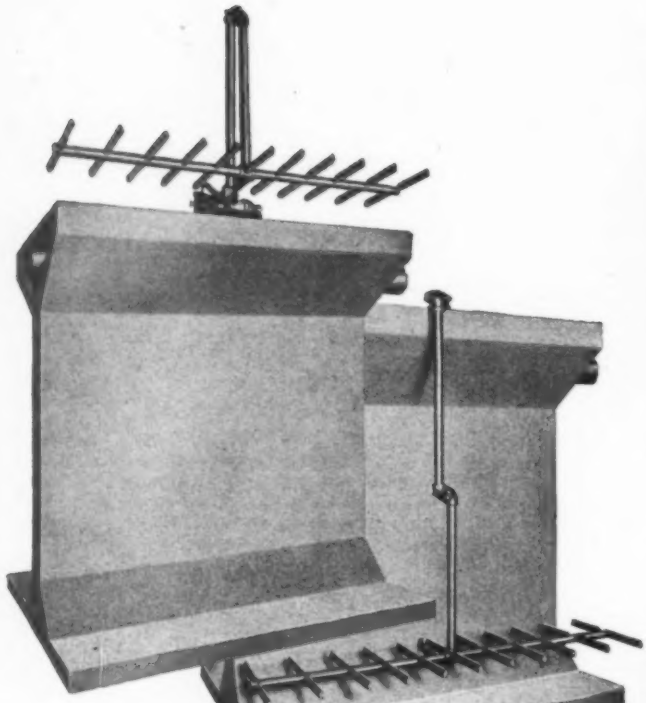


Fig. 2914—Swing Diffusers
Controlled aeration for the Activated Sludge Process. For towns of 4,000 and up. Diffuser tube assembly can be raised to tank walk. Simple regulation of air supply from tank walk. Tube cleaning without dewatering tanks or interrupting operation. Ask for Bulletin 175.

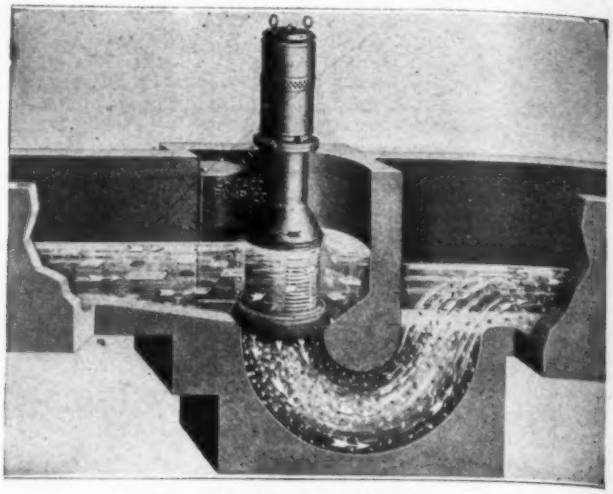


Fig. 2202—Comminutor
Eliminates screenings and screenings disposal—No burial; No incineration. Cuts coarse sewage matter into small settleable solids without removal from the channel.

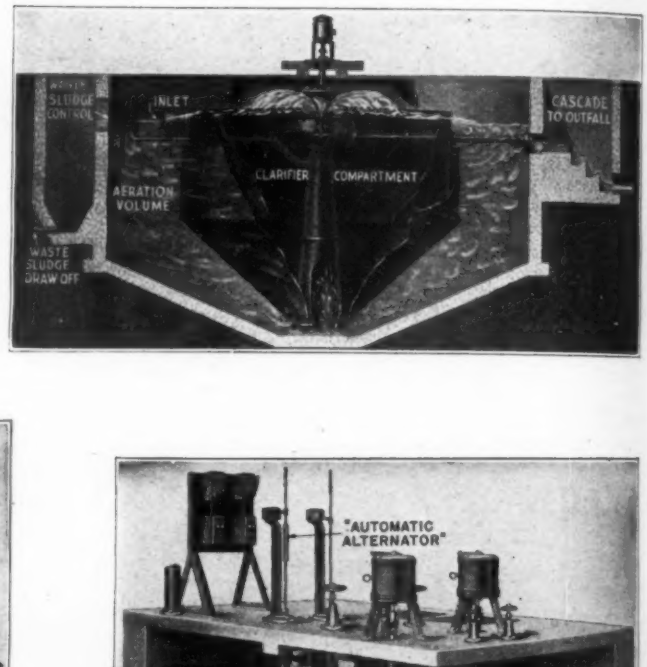


Fig. 2349 (right)—Combination Aerator-Clarifier
providing complete treatment of sewage without odor nuisance and with minimum manual operation. Ideal for housing projects, small camps, institutions, and small towns. **Over 75 units operating successfully.** Ask for Bulletin 128-K.

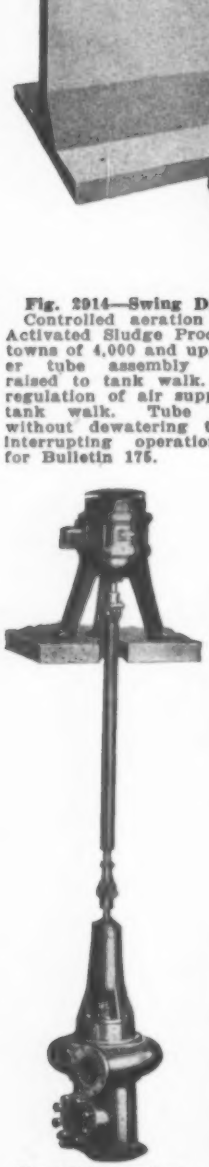


Fig 2504—Vertical Open-Shaft Non-Clog Pump
Universal Flexible Couplings in shaft compensate for misalignment. Ask for Bulletin 126.

Fig. 1860—Scru-Feller Primary Sludge Pump
Screw conveyor in the suction ahead of the impeller. Stellited cutters prevent clogging. The capacity can be varied instantly. Ask for Bulletin 190.

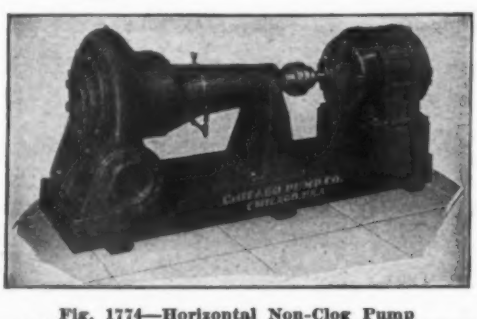


Fig. 1774—Horizontal Non-Clog Pump
Being mounted directly on base prevents pump being pulled out of alignment by long lines of piping. Ask for Bulletin 127.

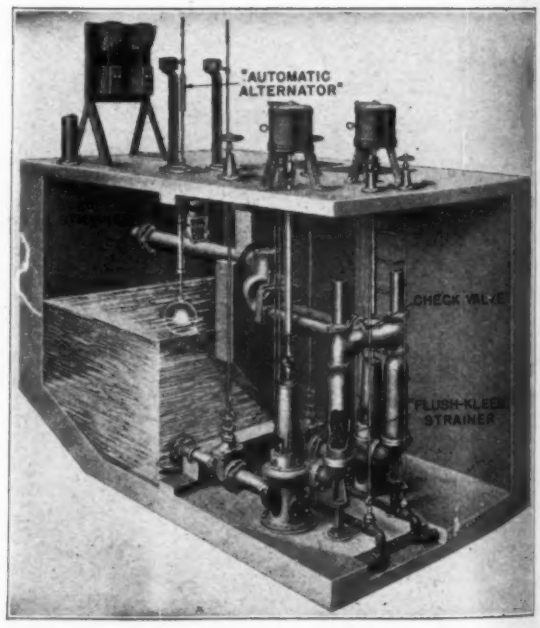


Fig. 2038—Flush-Kleen Sewage Pumping Station
Requires no attention. NEVER CLOGS. Automatically backwashes strainer. Keeps solids from basin and pumps. Impeller handles water only. Coarse sewage matter is stopped by Flush-Kleen strainer and is flushed out through discharge pipe. Check valve prevents discharging back through inlet line. Ask for Bulletin 122.

EXPERIENCE IN DIFFUSED AIR ACTIVATED SLUDGE PLANT OPERATION*

By W. H. WISELY
Exec. Secy., Fed. of Sew. Works Assns.

THIS review of activated sludge plant control practice is based on data and comments furnished by some 25 plant superintendents and chemists, who, even in these "questionnaire-able" days, found the time to set forth their procedures in a most detailed blank form. The complete co-operation of the following contributors is gratefully acknowledged:

Adams, J. K., Superintendent, Tenafly, New Jersey.
Ahrens, G. C., Superintendent, Omaha, Nebraska.
Allen, Wm. A., Superintendent, Pasadena, California.
Anderson, C. George, Superintendent, Rockville Center, N. Y.
Anderson, R. A., Superintendent, Muskegon Heights, Mich.
Barton, Ben H., Chief Operator, Findlay, Ohio.
Berg, E. J. M., Superintendent, San Antonio, Texas.
Bloodgood, Don E., Manager, Indianapolis, Indiana.
Bolenius, R. M., Chemist, Lancaster, Pennsylvania.
Brunner, Paul L., Chief Chemist, Fort Wayne, Indiana.
Collier, J. R., Superintendent, Elyria, Ohio.
Edwards, Gail P., Chief of Laboratories (Wards Island), New York City.
Froehde, F. C., City Engineer, Pomona, California.
Harris, R. C., Commissioner of Works, Toronto, Ont., Canada.
Henry, B. F., Superintendent, Pomona, California.
Larson, C. C., Chemist in Charge, Springfield, Illinois.
Lehmann, A. F., Superintendent, Hackensack, New Jersey.
Montgomery, J. R., Chemist, Pontiac, Michigan.
Munroe, E. H., Superintendent, York Township, Canada.
Philhower, Sara K., City Chemist, Gastonia, North Carolina.
Rhoads, Edward J., Superintendent, Lancaster, Pennsylvania.
Smith, E. E., General Superintendent, Lima, Ohio.
Turner, J. R., Superintendent, Mansfield, Ohio.
Wheeler, C. E., Jr., Engineer of Operation (Calumet Plant), Chicago, Illinois.

It is intended here to present data and comment on practical methods of controlling the principal operating variables, thus supplementing the elaborate committee report compiled by Langdon Pearse, chairman, and the sewage disposal committee of the American Public Health Association (see *Sewage Works Journal*, 14, 3, January, 1942). Only diffused-air activated sludge plants are represented in this study.

Insofar as the operator is concerned, there are five primary variables over which control can be exercised in an activated sludge plant.

1. Concentration of mixed liquor solids.
2. Rate of sludge return.
3. Rate of air application.
4. Aeration period.
5. Condition of the sludge.

These variables must be correlated into balance under the local conditions of load imposed upon each individual plant, and varied to meet seasonal and other fluctuations in load. Furthermore, the operator must view the variable factors as being interdependent, in the sense that any adjustment made in one of them may require manipulation of one or more of the others.

As a preliminary to the operation practices followed in the plants contributing to this summary, general data concerning each are given in Table I. It will be noted that a wide range in size, type, design and loading is represented.

Concentration of Mixed Liquor Solids

Most authorities regard control of the mixed liquor solids concentration, accomplished by apportionment of the activated sludge from the final settling tank between return and waste, as the most important of all operating variables. Certainly the recognition of this fact in recent years, with the resulting trend toward reduction of mixed liquor solids from the very high values formerly carried, has marked a notable advance in control practice.

Table II lists the average and range in mixed liquor solids carried in the aeration tanks of 21 plants. Thirteen of the plants reported show average concentrations of 1,500 to 2,500 p.p.m. to be used; at only three is the average less than 1,000 p.p.m. Four plants are also shown to average concentrations over 2,500 p.p.m., with the highest value (3,100 p.p.m.) at Lancaster, Pa. The variation in aeration solids carried, as indicated by the range in each plant, is interesting because the difficulty of close control is illustrated.

*A summary published in The Operator's Corner of Sewage Works Journal, pp. 909-936, Sept., 1943. Reprinted by permission.

With the exception of one or two cases reported, it will be noted that lower sludge indexes are achieved where mixed liquor solids in the higher ranges are carried and that higher sludge indexes seem to accompany low mixed liquor solids values. This possibly indicates that sludge of better settling characteristics and higher density is usually obtained in the mixed liquor solids range of 2,000 to 3,000 p.p.m. than at lower concentrations, substantiating the general belief that more stable operation under shock loads is to be expected in the higher range.

At Calumet (Chicago), Wheeler endeavors to hold 2,500 to 3,000 p.p.m. of mixed liquor solids, although the upper limit is often exceeded during and following storms when the ash content of the sludge increases. It is considered desirable to hold the volatile solids content of the mixed liquor above 1,500 p.p.m. in this plant. Brunner at Fort Wayne is also primarily interested in the volatile content rather than the total suspended solids in the mixed liquor, reported as follows:

"Control of the mixed liquor solids is maintained at 1,500 p.p.m. volatile solids rather than any optimum value of suspended solids.

TABLE I.—GENERAL INFORMATION REGARDING CONTRIBUTING PLANTS

Plant	Average Flow (m.g.d.)	Average Primary Sedimentation Period (Hr.)	Aeration — Type	Aeration — Aeration (Hr.)	Average 5-Day B.O.D. Raw Sewage (p.p.m.)
Chicago (Calumet)	85	0.25	Spiral	4.0	93
Elyria, Ohio	2.5	1.67	Spiral	5.5	353
Findlay, Ohio	2.3	3.1	Spiral	5.5	405
Ft. Wayne, Ind.	17.6	1.3	Spiral	8.6	199
Hackensack, N. J.	3.2	3.2	Comb. (1)	12.0	200
Indianapolis, Ind.	53.3	None	Spiral	8.4	272
Lancaster, Pa. (North)	3.3	2.9	Spiral	13.7	209
Lima, Ohio	7.7	1.4	Spiral	4.8	134
Mansfield, Ohio	3.1	2.3	Comb. (1)	7.4	237
Muskegon Hts., Mich.	1.2	3.1	Comb. (1)	6.3	322
New York (Wards I.)	184	1.2	Spiral	4.5	167
North Toronto, Ont., Can.	7.3	2.0	Spiral	6.0	280
Omaha, Neb.	3.3	2.0	Sw.D. (2)	7.5	241
Pasadena, Calif.	9.5	None	Sp. & R.F. (3)	6.9	151
Pomona, Calif.	1.7	—	F.D. (4)	8.3	—
Pontiac, Mich.	4.2	0.9	Spiral	5.0	208
Rockville Centre, N. Y.	2.3	0.8	F.D. (4)	4.4	292
San Antonio, Tex.	22	0.5	Spiral	5.9	225
Springfield, Ill.	8	2.0	Spiral	8.7	165
Tenafly, N. J.	0.7	—	Spiral	7.3	144
York Twp., Can.	3.1	None	Spiral	4.3	—

(1) Combination diffused air and paddles.
(2) Swing diffusers.
(3) Both spiral and ridge-and-furrow tanks.
(4) Fixed diffuser tubes.

TABLE II—MIXED LIQUOR AND RETURN SLUDGE CONTROL

Plant	Mixed Liquor Solids (p.p.m.) Average	Mixed Liquor Solids (p.p.m.) Range	Return Sludge Av. Return Rate (%)	Return Sludge Av. Solids (p.p.m.)	Average Sludge Index
Chicago (Calumet)	2,850	1,720-3,870	22	15,700	45
Elyria, Ohio	2,270	700-3,600	29	11,600	52
Findlay, Ohio	1,500	500-4,000	26	5,000	150
Ft. Wayne, Ind.	2,320	1,400-4,100	27	9,700	111
Hackensack, N. J.	1,600	900-2,500	23	10,000	130
Indianapolis, Ind.	2,500	400-3,700	41	8,000	98
Lancaster, Pa. (North)	3,100	2,700-3,600	31	13,800	49
Lima, Ohio	1,720	1,140-3,110	33	7,200	92
Mansfield, Ohio	1,040	940-1,140	20	3,650	346
Muskegon Hts., Mich.	900	400-2,000	41	4,300	100
New York (Wards I.)	1,770	1,075-3,050	45	4,775	170
North Toronto, Ont.	2,300	1,500-3,500	19	13,500	93
Omaha, Neb.	1,685	1,240-2,300	45	4,320	74
Pasadena, Calif.	1,100	980-1,340	12	6,700	189
Pomona, Calif.	...	.....	...	....	...
Pontiac, Mich.	2,500	2,000-3,000	20	....	125
Rockville Centre, N. Y.	730	2,000-3,000	3.5	26,700	40
San Antonio, Tex.	1,500	.....	42	4,200	210
Springfield, Ill.	1,750	725-2,500	30	6,500	121
Tenafly, N. J.	2,340	2,120-2,670	34	12,550	103
York Twp., Toronto, Can.	570	370- 800	38	....	...

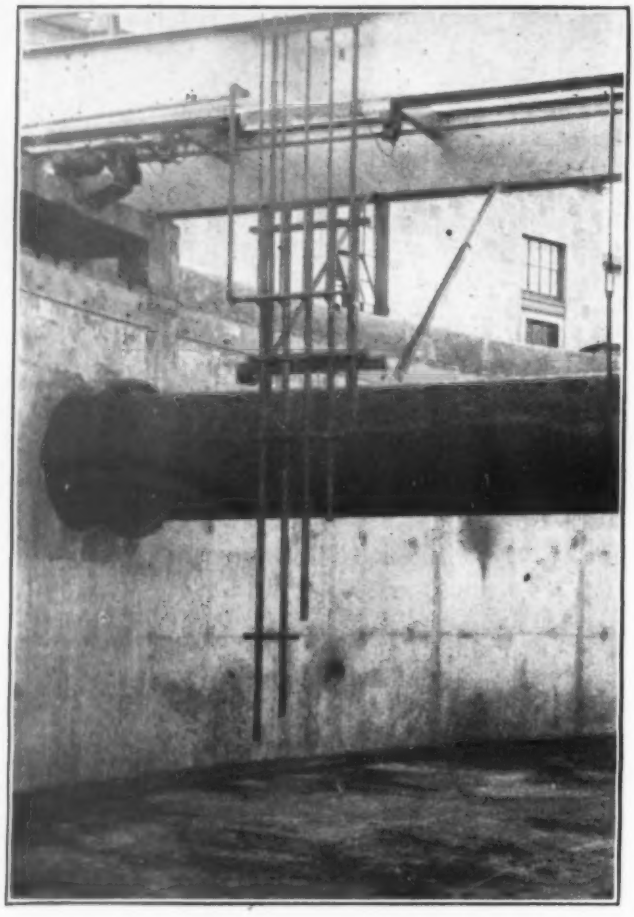


Fig. 1.—Air-lift bubbler for sludge blanket determination in final settling tanks at Fort Wayne, Ind.

It is necessary to run on this basis because of frequent slugs of river water which bring in fine silt and thus add weight to the solids. If we were to waste on the basis of a 2,000 p.p.m. suspended solids level during these periods, we would not have much active sludge in the mixed liquor."

At Indianapolis, Bloodgood found it desirable to carry the highest mixed liquor solids concentration possible with the amount of air available:

"It is our belief that more solids can do more work if adequately supplied with air. Every effort is made to keep the mixed liquor solids at a uniform concentration so as to eliminate the piling up of solids in any particular part of the plant. The solids are determined daily from composite samples and the amount of sludge to be wasted is gaged from the concentration found to be present."

Andersen at Rockville Centre, N. Y., at which plant the activated sludge treatment is followed by mechanical filtration of the effluent, defines the optimum mixed liquor concentration as "only that quantity (of solids) requisite to purify properly the sewage, while also insuring an excess of oxygen to maintain the health of the biological life." A very active sludge is present in this plant, averaging 88 per cent volatile solids. Operating conditions are also unusual in that an extremely dense return sludge (27,000 p.p.m. solids) prevails in normal operation. Under these conditions of balance, it has been possible to eliminate the effluent filtration for the past eight months with "the sludge index, settling of solids and sludge production stabilized to an apparently foolproof extent."

Larson (Springfield, Ill.) and Lehmann (Hackensack, N. J.) refer to the common need for adjustment of the mixed liquor solids to seasonal variations. Comparison of practice in these two plants, however, furnishes an excellent example of the effect of local conditions on plant control. Heavy loads received for treatment at Hackensack in summer months require about 2,000 p.p.m. of mixed liquor solids concentrations as against 1,600 p.p.m. in winter. At Springfield, higher volatile matter percentages in summer permit some reduction in the suspended solids carried. Turner (Mansfield, O.) checks occasionally for varying trends by trying lower and higher concentrations but thus far has always returned to a value of about 1,000 p.p.m.

Physical features of plant design may limit the flexibility of solids control, as at Muskegon Heights, Mich., where the air capacity and sludge return facilities are critical. Superintendent Anderson states:

"The solids concentration is governed by the load received from the primary tanks, dissolved oxygen in the final settling tanks in comparison with that in the last aeration tank, nitrate production and to a large extent upon our sludge withdrawal facilities. The latter have never permitted carrying more than 2,000 p.p.m."

Allen at Pasadena gives primary attention to the concentration of solids in the return sludge and finds that the mixed liquor solids concentration is controlled incidentally. His experience indicates 6,500 to 8,000 p.p.m. of return sludge solids result in best operation with about 1,200 p.p.m. of mixed liquor solids. Return sludge solids are estimated twice daily by centrifuge determinations.

Based on the experience represented here and some reference to the APHA committee report noted previously, the following summarizing comments regarding mixed liquor solids control are offered:

1. Concentrations of 1,500 to 2,500 p.p.m. of suspended solids in the mixed liquor appear to constitute general practice, although values above or below this range are often encountered where plant limitations and unusual local conditions are involved.
2. There appears to be an increasing trend toward recognition of the volatile matter content of the mixed liquor solids as a control factor rather than the suspended solids. This appears logical since the volatile matter is actually the active constituent of the sludge. A minimum volatile solids concentration of 1,500 p.p.m. is recognized as a control threshold in two of the plants represented.
3. It is suggested that there be no hesitancy in varying the mixed liquor solids to meet seasonal variations in load and temperature.
4. The importance of keeping the mixed liquor solids concentration within any limitations imposed by the air supply is emphasized. Proper operation cannot be obtained when the solids content is so high that the available air supply is inadequate to maintain an aerobic environment.
5. While low concentrations of solids may result in economy of power (for air supply) the volatile content and activity will be high whereas high solids concentrations usually yield less active but denser sludges which are more conducive to stable operation under shock loads and afford a somewhat higher degree of purification.
6. The rate of activated sludge accumulation or build-up is usually greater when the mixed liquor solids concentration is in the low range; the resulting high volatile content is desirable from a fertilizer production standpoint but entails closer control in avoiding septicity during compaction in the final settling tank.
7. High mixed liquor solids concentrations are ordinarily advantageous from the sludge disposal standpoint, since part of the volatile matter is oxidized during the aeration process and the greater stability of the sludge permits it to be concentrated to a lower moisture content before waste to disposal facilities.

Rate of Sludge Return

The rate at which the activated sludge is returned to the aeration tanks generally determines the condition of the sludge. Too low a rate of return may result in septicity and consequent bulking and other evils; too high a return rate may not allow sufficient time for concentration in the final settling tank and thus results in a light, voluminous sludge, creating problems in disposal of the excess going to waste. Obviously, the rate of return is important as regards mixed liquor solids control and a balanced procedure must be achieved.

Rates of return (expressed as percentages of the sewage flow), with return sludge suspended solids data, are listed in Table II. Of the 21 plants listed, 8 employ return rates between 20 and 30 per cent, 10 employ rates between 30 and 45 per cent and only 3 return at rates under 20 per cent. The very low return rate of 3.5 per cent practiced at Rockville Centre is largely explained by the very high solids concentration of 26,700 p.p.m. in the return sludge. In winter the solids concentration becomes as high as 35,000 p.p.m.—a remarkable condition when the unusually high volatile content (88 per cent in mixed liquor) is considered.

Examination of the return sudge suspended solids data contained in Table II indicates that it is difficult to determine a "normal" range. Nine of the plants achieve return sludge concentrations of 4,000 to 8,000 p.p.m. and seven plants report average values between 10,000 and 15,000 p.p.m. As is to be expected, it will be noted that the concentration of return sludge

solids is generally, although not always, lower at the higher rates of return.

The APHA committee report includes an interesting analysis of return sludge practice in the data showing the "ratio of return solids to incoming solids at aeration tanks." Ratios between 10:1 and 39.6:1 are shown for eleven plants; however, seven of these plants reported ratios between 10:1 and 20:1. These figures may possibly be better visualized if regarded as "pounds of suspended matter returned as activated sludge per pound of suspended matter in the sewage received for treatment at the aeration tank."

In his regulation of the rate of sludge return, the operator is almost always guided by the depth of accumulation or sludge blanket in the final settling tanks. Too deep a sludge blanket may result in septicity of the sludge and upset of the biological balance; too shallow or no blanket may yield a thin, poorly concentrated return sludge. Seasonal changes in temperature and volatile content of the sludge often necessitate variation in the return rate.

At Fort Wayne, Brunner gives much credit to the air-lift bubbler piping (Fig 1) which affords a constant indication of the sludge depth in the final settling tanks at that plant. An excessively deep sludge blanket due to bulking or insufficient return is revealed immediately by the bubbler system and the return rate is increased accordingly. Automatic sludge level indicators utilizing photo-electric cells have been employed with varying degrees of success.

Lehmann at Hackensack considers the sludge blanket level as a most important control and makes hourly observations for the purpose of return sludge flow regulation. Particularly close supervision of the sludge blanket is also necessary at Pasadena, where generally high temperatures and high volatile matter content induce rapid septicity in the sludge accumulation if held too long in the final settling tank for thickening. Similar difficulty is experienced at Omaha, where packinghouse wastes and surges of septic sewage solids from the combined sewers after rains create a problem. Ahrens reports that increased rates of sludge return at such times maintain the sludge in better condition and are beneficial in freshening the mixed liquor. This not uncommon practice of returning sludge at very high rates to smooth out shock loads is suggestive of the recirculation theory as applied to modern trickling filter treatment—concentration of the return sludge being sacrificed for the dilution effect of the effluent in which the sludge is suspended. The thin return sludge, however, introduces other problems in connection with waste and disposal.

Smith at Lima employs an increased sludge return rate at the apparent onset of bulking of sludge, which common operation difficulty will be discussed in more detail later. A semi-automatic return sludge rate controller has been developed at the Lima plant, by adapting a weighted plug valve to the return sludge pump discharge piping. The arrangement is shown diagrammatically in Fig. 2 and its operation is described by Smith as follows:

"A 4-inch valve in the return sludge pump header continuously discharges excess activated sludge to the primary settling tank for removal from the secondary system. The amount of such excess sludge is affected immediately by a back-pressure plug (Fig. 1) in the discharge of return sludge to the mixed liquor channel and *generally* by the settling rate of aerated sludge in the final settling tanks through control of the suction lift of the return sludge pump. Specifically, operating directions call for the individual sludge discharge valves between the final settling tanks and the return sludge well to be throttled at all

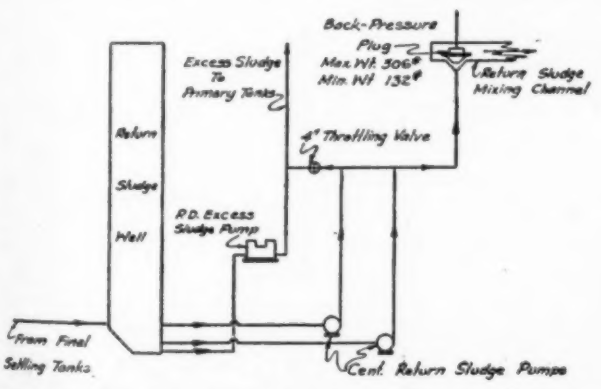


Fig. 2.—Diagram of return and excess sludge control arrangement at Lima, Ohio. E. E. Smith, Superintendent.

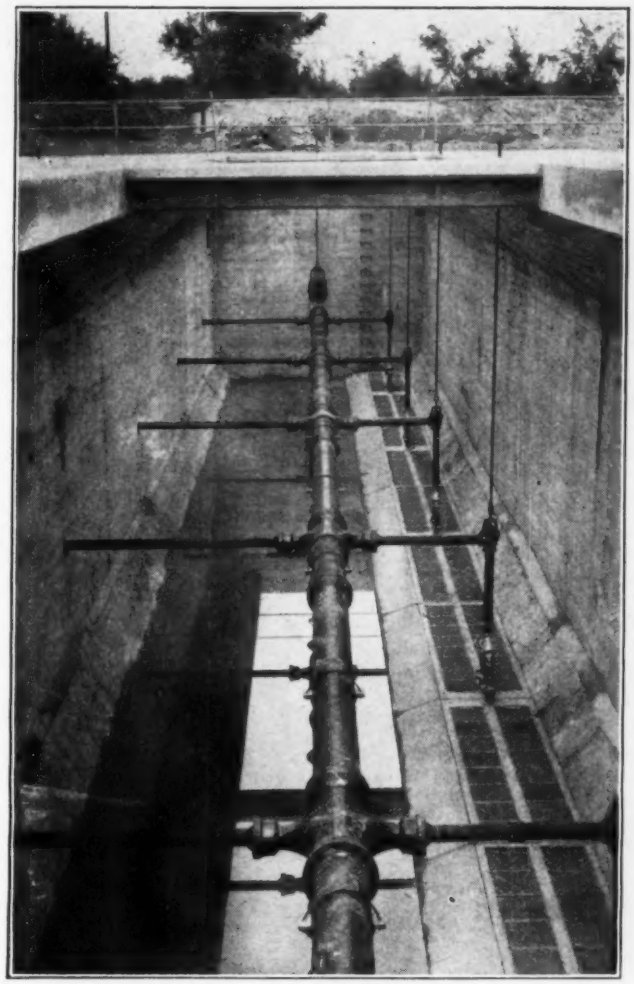


Fig. 3.—Empty aeration tank at Springfield, Ill., showing air piping and plate containers.

times sufficiently only to hold the sludge line in the final settling tanks at the edge of the vertical side-walls, maintaining the three foot cone in the final tanks full of sludge. If the rate of settling increases (or, conversely, the hourly percentage settling decreases) the more compact sludge will require less volume in the return and excess flows, the opposite conditions obtaining with a slower settling sludge.

"The back-pressure plug in the return sludge discharge, with empirically determined amount of weight will proportion the excess flow according to the rate of return and, indirectly, the sludge settling rate. Operating directions also call for some correction when the solids in the aeration effluent exceed a set figure. Thus, for the summer of 1941, when the solids in the aeration effluent exceeded 1,500 parts per million, the 4-inch return sludge bleeder valve was closed and the 50 g.p.m. excess sludge diaphragm pump operated for the three-hour period between 5:00 and 8:00 a. m. the day following that on which the determination of aeration effluent suspended solids was made. This three hour pumping seemed to be sufficiently in excess of the normal production of secondary solids so that no great deviation from the desired amount of solids followed such procedure.

"The arrangement may be called semi-automatic control of mixed liquor solids, as the system involves no effort on the part of the superintendent to make any detailed schedule of excess pumping as such. During the earlier part of the year when run-off provided a weaker combined sewage, the setting of 1,000 p.p.m. for aeration effluent was easily obtained by increasing the weights on the return sludge discharge plug. In addition to relieving the operators from the necessity of guessing at the number of hours of excess sludge pumping, this system has the following advantages:

"(1) Nearly eliminates the operation of the excess sludge pump, with its eight rubber diaphragms and four rubber ball valves, avoiding their maintenance.

"(2) Greatly reduces power for direct excess sludge pump motor operation, saving about $10.00 per month.

"(3) Has an apparent beneficial effect on primary settling, in that acting as a coagulant, the results from adding continuously small amounts of excess activated sludge are preferable to adding the same volume over shorter periods."

Rate of Air Application

Maintenance of aerobic conditions throughout the activated sludge process (aeration and final sedimentation) is essential to proper operation. Since the provision of an adequate air supply at suitable pressure almost always constitutes the principal operation cost item, the operator must exercise such control of air application that there is a sufficient quantity to afford stirring of the mixed liquor with a residual of dissolved oxygen in the mixed liquor during aeration, but to avoid the waste of power, undesirable changes in the activated sludge and over-nitrification of the effluent which occur when the air application is excessive.

The quantities of air applied in the plants represented in this review of operation practice are shown in Table III, and are expressed in cubic feet per gallon of sewage treated as well as cubic feet per pound of 5-day B.O.D. removed. The latter unit is rapidly gaining favor among operators as being most informative and more indicative of the manner of air utilization. Of the plants listed, nine show air requirements of 350 to 850 cu. ft. per pound B.O.D. removed and at only two, Omaha and Rockville Centre, is it found that more than 1,500 cu. ft. is required. The maximum application of 2,180 cu. ft. per pound B.O.D. removed at Rockville Centre may be explained by the intensely dense and active return sludge, which has been commented upon previously. In reviewing these data, it must be kept in mind that strict economy of air application is not so essential at plants equipped with sludge gas engine operated blowers such as at Findlay, Fort Wayne, Omaha, Rockville Centre, Springfield and others, in which circumstances liberal quantities of air may be used.

On the basis of the sewage volume treated, the average air application values in Table III range from 0.35 to 2.0 cu. ft. per gallon, with fairly general distribution between these limits.

TABLE III—APPLIED AIR QUANTITIES AND MIXED LIQUOR OXYGEN CONTENT

Plant	Applied Air (Cu. Ft.) Per M. G. Average	Range	Av. Per Lb. B.O.D. Removal	D.O. During Aeration (p.p.m.) Inlet	Midpoint	Outlet
Chicago (Calumet)	0.35	0.22-0.52	500	...	...	1.5-5.0
Elyria, Ohio	0.94	0.65-1.55	1290	...	...	...
Findlay, Ohio	0.70	0.30-1.00	840	0	1.0	3.0
Ft. Wayne, Ind.	0.99	0.49-1.65	835	0.8	2.0	5.2
Hackensack, N. J.	0.60	0.41-1.10	640	0-3.0	0.5-3.0	0.5-3.0
Indianapolis, Ind	1.78	0.83-4.80	1020	...	...	2.0+
Lancaster, Pa. (North)	0.70	0.50-0.90	830	1.8	...	5.2
Lima, Ohio	0.99	0.45-1.52	1415	2.2	5.0	4.9
Mansfield, Ohio	0.37	0.21-0.40	370	...	...	2.9
Muskegon Hts., Mich.	0.47	0.29-0.57	345	0	1.0	2.3
New York (Wards I.)	0.57	0.38-0.75	470	...	...	3.4
North Toronto, Ont.	1.00	0.70-1.30	620	...	...	...
Omaha, Neb.	1.36	1.02-1.86	1650	...	...	3.2
Pasadena, Calif.	1.62	1.47-1.89	1450	...	...	3.8
Pomona, Calif.	1.80	0.95-3.00	....	...	...	3.0
Pontiac, Mich.	1.10	.....	1470	...	...	5.0
Rockville Centre, N. Y.	2.00	1.70-2.30	2180	Tr.	1.5	2.5
San Antonio, Tex.	1.34	.....	970	...	...	...
Springfield, Ill.	0.75	0.43-1.10	950	2.0	4.0	6.0
Tenafly, N. J.	1.47	0.90-2.30	1295	...	...	...
York Twp., Toronto, Can.	1.70	1.60-1.90	....	4.6	2.7	2.7

The variation in applied air in each of the plants is not entirely due to manipulation by the operator because the unit "cubic feet per gallon" is subject to variations in the rate of sewage flow received for treatment. Comparison of the cubic feet per gallon values with the figures representing cubic feet per pound B.O.D. removed in the plants at Chicago Calumet, North Toronto, Omaha and San Antonio will indicate clearly how misleading the former basis of expressing air application may be.

The concentration of dissolved oxygen in periodically collected samples of mixed liquor is the most commonly employed control for determination of the adequacy of air application (Table III). The frequency of such mixed liquor sampling and dissolved oxygen determinations varies from 1 to 12 times daily, with most operators using a routine 4-hour schedule. From Table III it will be observed that many operators determine the mixed liquor dissolved oxygen content at the inlet and midpoint of aeration as routine control in addition to D.O. determination at the aeration tank outlet. Brunner at Fort Wayne supplements his 12-hour aeration tank effluent sampling routine with a dissolved oxygen survey through each aeration tank at least once a month.

The mixed liquor dissolved oxygen data in Table III illustrate the progressive increase in residual oxygen which is nearly always found to occur during aeration. Although it is not uncommon to find a complete absence of dissolved oxygen at the aeration tank inlet, it is generally held desirable for some residual to be present throughout the entire aeration period. Residual oxygen must certainly be present at the midpoint of the aeration period if normal results are to be obtained. The midpoint oxygen concentration is considered the primary control at Toronto.

It has been demonstrated experimentally and in practice that a normally active sludge uses, in the first two hours of aeration, about 50 per cent of the total amount of air it requires. This finding constitutes the basis for the practice of tapered aeration, whereby air application is heaviest at the inlet end of the aeration units and gradually reduced to a minimum at the outlet end. Most of the larger plants do not employ tapered aeration although the principle has many enthusiastic supporters.

In controlling air application by means of the dissolved oxygen content of the aerated mixed liquor, Lehmann at Hackensack seeks to maintain from 1.0 to 2.0 p.p.m. and makes adjustment on the basis of observations every two hours. Such unusually close control appears to be required by a sensitive activated sludge which affords a narrow margin between under and over-aeration. At Omaha, Ahrens considers 1.5 p.p.m. as the lowest desirable dissolved oxygen limit. A minimum of 2.0 p.p.m. appears to be the most commonly recognized control value and is employed at Fort Wayne, Indianapolis and other plants. Wheeler at Chicago (Calumet) encounters seasonal factors which lead to the use of a 1.5 p.p.m. control in summer and 2.0 p.p.m. in winter. At Wards Island Edwards finds it desirable to have about 5.0 p.p.m. at the aeration tank outlets at all times.

The dissolved oxygen content of the plant effluent is, of course, a most important item and is often recognized as the principal control, as at Lima, or is considered in conjunction with the mixed liquor oxygen concentration, as at Fort Wayne, Wards Island and Omaha. At Lima, Smith attempts to maintain at least 3.0 p.p.m. of dissolved oxygen in the plant effluent and finds that 3.5 to 4.0 p.p.m. must be held in the aerated mixed liquor to achieve the desired end result.

Brunner (Fort Wayne) and Turner (Mansfield) direct attention to the particular significance of mixed liquor dissolved oxygen determinations made at critical flow periods during the day. Turner is guided entirely in adjustment of air application by the decrease in dissolved oxygen which occurs during the peak load period of 10:30 a.m. to 2:00 p.m. If the dissolved oxygen drops as much as 75 per cent in this time, air application is increased; if the drop is as low as 50 per cent, less air is used. This procedure appears to have particular merit where shock loads are received.

Where there is poor flexibility of air supply, as at Elyria, or inadequate blower capacity, as at Muskegon Heights, the mixed liquor oxygen content can be controlled only by variation of the concentration of mixed liquor solids carried. Barton (Findlay) and Rhoads (Lancaster) find it desirable to maintain a constant rate of air application and to make adjustment only by increasing or decreasing the mixed liquor solids, even though no design limitations affecting the air supply are involved in these plants.

An interesting observation is offered by Lehmann regarding use of the mechanical paddles used in combination with diffused air at Hackensack. It is found that a decrease in mixed liquor dissolved oxygen occurs when the paddles are started, apparently demonstrating their effectiveness as a mixing device. The paddles are operated only during the summer months of heaviest load.

At Tenafly, New Jersey, Adams finds that more air must be applied than is required for biological balance of the activated sludge in order to maintain proper admixture and circulation of the mixed liquor.

Aeration Period

Although discussed here as an operating variable, the control of the aeration period by actually varying the detention time in aeration units is not common in practice, since few diffused air activated sludge plants have the excess aeration tank capacity necessary to make the procedure possible. It is feasible, however, for the operator to utilize the available aeration tank capacity in various ways, as by reaeration or by "adjusted aeration" (used at Findlay, Ohio), both of which procedures are discussed below.

The aeration periods available in the plants represented in this study are shown in Table I. At ten of the plants listed, periods between 4 and 6 hours are found; at five plants the aeration periods are within the 6 to 8 hour range, and periods in excess of 8 hours are reported at the remaining six plants. In view of

the wide variation in available plant capacity thus indicated, it is not surprising that there exists such a broad range in operating practice in regard to mixed liquor solids concentration, rate of sludge return and rate of air application. All of these more readily controlled variables must be adapted to suit the less flexible aeration period.

Longer aeration periods usually yield a higher degree of purification with more advanced nitrification. At some plants, at which algae growth in the outlet watercourse may present a problem, such higher nitrification may be a disadvantage rather than desirable. Short aeration periods ordinarily require more "high-pressured" operation, unless a weak sewage is received for treatment, and demand more care on the part of the operator in developing and maintaining a well-conditioned activated sludge. The plant having liberal aeration capacity is usually less subject to upset by shock loads, as at Lancaster, Pa., and Pontiac, Mich.. At Pontiac the activated sludge plant is augmented by a separate trickling filter plant, hence a constant, controlled sewage flow is handled by the former works, greatly simplifying all phases of operation.

Lehmann at Hackensack suggests the desirability of plant design details permitting flexibility in aeration capacity. Faulty hydraulics apparently make it impossible to remove aeration tanks from service as may be desired.

Return Sludge Reaeration.—Routine, continuous reaeration of the return activated sludge before admixture with the aeration influent sewage is practiced in only two of the plants contributing to this study, *i.e.*, San Antonio and Pasadena. At the latter plant a 45 to 80 minute reaeration period is utilized primarily as a means of return sludge distribution. Reaeration is employed at Muskegon Heights on occasion "to lighten a too heavy sludge and to relieve floating sludge conditions in some cases." Anderson (Muskegon Heights) refers to the highly volatile activated sludge, particularly since packinghouse wastes have been received, and difficulty in properly conditioning the sludge with an inadequate air supply as being the causes for resorting to reaeration. When the sludge approaches a septic condition, reaeration is accomplished by discharging a portion of the return sludge to the last aeration tank, at a point about 25 feet from the outlet end. Air application to this unit is correspondingly increased.

The following local conditions justify the practice of return sludge reaeration by Berg at San Antonio:

1. A strong sewage containing industrial wastes, subjecting the plant to abrupt increases in load as when sudden flushing of sewers occurs.
2. High prevailing temperatures which induce septicity in the sewage and activated sludge solids.
3. Budgetary restrictions on power purchases, resulting in some limitation of air supply.
4. Unusually wide variation in rates of sewage flow, resulting in extremely long final settling tank detention periods in the early morning hours.

A reaeration period of about 0.9 hour is employed at San Antonio, as compared to the mixed liquor aeration time of 5.9 hours. The reaerated sludge averages about 4,200 p.p.m. and settles to 88 per cent after 30 minutes as compared to 1,500 p.p.m. and 33 per cent, respectively, for the mixed liquor. Air application was at the rate of 880 cu. ft. per pound of 5-day B.O.D. in the aeration influent sewage although Berg concludes that 1,000 cu. ft. per pound applied B.O.D. is the minimum quantity which will maintain a well-conditioned sludge under San Antonio conditions.

There are two fundamental principles in general acceptance which should be recognized when return sludge reaeration is considered: first, that the air application facilities must be of adequate capacity to maintain aerobic conditions in the reaeration unit, and, second, that prolonged absence of food is likely to render the sludge inactive and low in oxidizing capacity.

"Adjusted Aeration" (Findlay, O.).—An interesting routine is employed by Barton at Findlay, O., during low flow periods to reduce the aeration time and to minimize the effect of surge flows which result in disturbance of the final tank sludge blanket with loss of sludge floc at the weirs. The method involves alternating the operation of the two aeration units at eight-hour intervals by the simple expedient of closing the valve on the discharge pipe to the final settling tank, thus permitting the unit thus shut off to "idle." The water level raises in the idling unit, creating an increased back pressure at the plates and diverting most of the air to the working unit. The resultant idling and working cycle actually effects a substantial measure of reaeration of the sludge and has apparently eliminated the surge influence at Findlay. In times of normal sewage flow, both aeration units are operated in parallel and in conventional fashion.

Condition of Activated Sludge

The condition of the activated sludge at any time reflects the end-point of all manipulations by the operator, hence is his most important guide. Were it not for the lack of constancy of the character and quality of the sludge, the operation of an activated sludge plant would offer no complications of consequence. The observations upon which most dependence is placed at this time in determining the condition of activated sludge are:

1. Appearance and odor.
2. Settling characteristics and density, observed by laboratory observation of the rate of settling and computation of the sludge index.
3. "Activity," as observed directly by measurements of the rate of oxygen utilization or as estimated indirectly from the proportion of volatile matter present.
4. Microscopical examination to ascertain the types and prevalence of the biological life present.

Other determinations of such factors as pH and dissolved oxygen afford information concerning the environment of the sludge.

Appearance and Odor.—When in good condition, activated sludge is ordinarily light to moderate brown in color, becoming dark brown to black as septicity may occur. The odor of well-conditioned sludge is sharply musty and not unpleasant but turns sour and disagreeable when in a very bad state. The flocs making up good quality sludge are of moderate size and have clearly defined edges; a poor sludge usually appears to take the form of spongy, fluffy masses. During times of extreme low temperatures, the flocs may become quite small and dispersed.

Settling Properties and Density.—The settling properties of activated sludge are the most significant indexes of the sludge condition since efficient operation is dependent on the ready separation of the sludge from the treated liquor in the final settling tank. Well-conditioned sludge normally occupies about 20 to 30 per cent of the mixed liquor sample volume after five minutes' settling in a graduated cylinder. The most common manifestation of poor sludge condition is "bulking" (to be discussed in detail below), in which state the sludge particles become light, enlarged and difficult to remove by sedimentation. The sludge index is an expression of the density of the sludge and is more informative than the settling test alone since it takes into account the amount of sludge solids contained in the mixed liquor sample. Sludge index values below 100 are generally considered representative of well-conditioned sludge although satisfactory operation may be accomplished with sludges having indexes in the order of 200, at Wards Island, Pasadena and San Antonio. It may be significant that the activated sludges in these plants are all of high volatile matter content. The effect of industrial wastes containing solids of high or low specific gravity should also be recognized in the interpretation of sludge index values and, particularly, in the determination of optimum operating ranges for a specific plant.

Sludge Activity.—The determination of sludge activity by measurements of oxygen utilization as developed by Bloodgood at Indianapolis has been adopted at a number of plants. By means of a machine developed for the purpose (see Sew. Wks. Jour., 10, 927, November, 1938), the amount of oxygen, in p.p.m. per hour, used by samples of mixed liquor from each aeration tank, is determined daily. This rate of oxygen utilization is termed the "sludge demand." The samples are taken from the outlet end of the aeration tank and concentrated to a standard value of 0.5 per cent solids for the measurement. The sludge from this test is then fed with synthetic sewage to produce a 0.5 per cent mixture and the rate of oxygen utilization again determined by the machine. The last determined rate minus the sludge demand yields an oxygen utilization rate, expressed in p.p.m. per hour, denoted by Bloodgood as "sludge activity." For best operating results at Indianapolis, the sludge demand must be kept in the range of 25 to 50 and the sludge activity should not exceed 70 to 100 p.p.m. per hour. The procedure is found useful in controlling air, mixed liquor solids, rate of sludge return and in ascertaining the shock overloads from industrial wastes. Further details will be found in Sew. Wks. Jour., 10, 26 (January, 1938).

Other devices, including the *Odeeometer,* have been used for determining rates of oxygen utilization by activated sludge and sewage-sludge mixtures.

In at least eight of the plants represented here, important significance is attached to the volatile matter content of the activated sludge as an operation control. Rhoads and Bolenius at Lancaster, however, find that there appears to be no uniform relationship between the volatile content and general characteristics of the sludge, but point out that this is probably due to industrial waste variations. At Chicago (Calumet) and Fort Wayne, the primary concern appears to be maintenance of the volatile suspended solids content of the mixed liquor above a minimum of 1,500 p.p.m., in order that a sufficiently active sludge will

obtain. At Wards Island, Mansfield, Muskegon Heights and other plants, operating difficulties and increased air requirements are attributed largely to high volatile solids contents of the return sludge. Turner at Mansfield reports that the volatile content of the return sludge solids averages about 80 per cent, which may explain the high prevailing sludge index (346). Increased quantities of slaughterhouse wastes received at Muskegon Heights raised the volatile suspended solids in the influent sewage from 65 per cent to 80-85 per cent, adding complications in operation control. The industry has been requested to install adequate grease removal and rate-of-flow control facilities in an effort to minimize the influence of the wastes.

Edwards, in comparing data from the New York Wards Island and Tallmans Island plants (Sew. Wks. Jour., 12, 1077, Nov., 1940), shows a marked relationship between the volatile solids content of the return sludge and the sludge index. The relatively high sludge index of 170 at Wards Island is held to be caused by the high volatile solids content of 76.1 per cent. Edwards suggests the sludge index may be a relative figure as an indication of bulking and that the variance in sludge indices encountered in comparing plant data may be explained by the differences in volatile matter content.

Edwards and Anderson (Muskegon Heights) both refer to the requirement of additional air application when the volatile content of the sludge is high, indicating that another important operation control relation may exist. There appears to be considerable justification for greater emphasis on the volatile solids determination in the mixed liquor and return sludge as an operation control, as well as for extensive study of the significance, interpretation and application of such data.

Microscopic Examinations.—Determination of the activated sludge condition by microscopic observance of the number and types of organisms present is practiced at most of the plants contributing to this study; however, the frequency of such examinations varies widely. At nine plants it is reported that the microscope is used "occasionally"; weekly sludge examinations are made at Lancaster and Pontiac; Edwards reports that five to six observations are made weekly at Wards Island. The occasional examinations made at Mansfield, Pontiac and Springfield are augmented by daily checks when the sludge index is high or when the sludge condition is otherwise doubtful. Bloodgood states that the microscopic observations are made seldom at Indianapolis "as it is believed that by the time there is a change in flora it is too late to make the necessary changes in operation procedure for maintenance of a good activated sludge."

At Wards Island, Edwards considers protozoa and filamentous forms as of most importance and finds flagellates to be numerous with low dissolved oxygen conditions. Larson at Springfield considers a preponderance of rotifera with ciliates such as *vorticella, carchesium, stentor,* and *paramoecium* to be present when the sludge is in good condition, an unsatisfactory sludge being characterized by the presence of *amoeba* and filamentous types including *Sphaerotilus natans.* Most common practice, typified by the procedures at Lancaster, Mansfield and Pontiac, is to check primarily for the filamentous growths, as these forms are almost always prevalent in a poor sludge and are readily identified.

Other Measures of Sludge Condition.—Lehmann at Hackensack employs pH determinations on mixed liquor samples during aeration as an indication of the degree of oxidation of the sludge. He finds that a drop in pH occurs during normal operation and that bulking occurs otherwise. Too low a pH, of course, is evidence of septicity and must be avoided by higher return rates. At Omaha, Ahrens also includes routine pH determinations on the mixed liquor and return sludge among his observations for place at a pH of 6.8 in the return sludge and includes the sludge condition. Adams at Tenafly finds best operation to take place at a pH of 6.8 in the return sludge and includes the determination in his daily routine.

Determination of the ammonia, nitrite and nitrate nitrogen on the plant effluent are obviously informative regarding the oxidizing and nitrifying properties of the activated sludge and are commonly performed as routine analyses. From 1 to 2 p.p.m. of nitrates in the plant effluent is generally considered to indicate a sufficiently nitrifying sludge. Effluent nitrate contents of more than 5.0 p.p.m. are unusual since most operators consider it uneconomical to carry nitrification beyond this point. At Pasadena, where high temperatures entail constant vigilance against bulking, Allen considers the presence of at least 1 to 2 p.p.m. of nitrates in the effluent as an important safety factor. Anderson at Muskegon Heights has found that methylene blue stability determination affords a quick and simple check on nitrate production and includes this test on the plant effluent in his routine. Immediate loss of color is considered to indicate a complete absence of nitrate nitrogen. Anderson also suggests that the turbidity determination may give indication of upset in sludge condition even though results of other determinations may appear satisfactory.

Bulking of Activated Sludge.—Well-conditioned activated sludge settles rapidly from the aerated mixed liquor leaving a sparkling, highly oxidized plant effluent. Loss of the rapid settling property and increase in the sludge index is usually an early indication of deteriorating sludge quality. As the flocs increase in size and lose density, the sludge blanket in the final settling tank increases in depth until the natural currents in the tank carry some of the solids over the weirs with the plant effluent. Avoidance of such bulking of the sludge is the most common problem encountered in operation and activated sludge plants in which it has never occurred are indeed rare. Of the plants represented here, "chronic" bulking is reported at four; one or more instances of bulking each summer are experienced at eight; at nine of the plants bulking is reported to occur infrequently or only "occasionally in mild form." Included in the last group are the plants at Hackensack, where no bulking has occurred in the past two years, and at Rockville Centre, where there have been no such difficulties in the past eight years, improved operation control being credited for these records in both cases.

The reported causes of bulking are summarized as follows:

1. Loss of balance between operation variables due to carelessness or relaxed vigilance in control is offered as the primary cause in six plants. Too high or too low mixed liquor solids concentration and inadequate air application are mentioned as specific reasons.

2. Shock loads from industrial wastes are held responsible for bulking experienced at five plants. Toxic wastes as from paint manufacture and metal plating plants, wastes of high organic content as from packinghouses and distilleries, and wastes containing appreciable quantities of oil and grease are considered most likely to result in interference. At Muskegon Heights and Lancaster, the industrial waste influence has been minimized by requiring such industries to effect removal of objectionable components and provide for uniform rates of discharge to the sewer system.

3. At four plants, high volatile matter concentrations, occurring usually in dry summer months when the raw sewage solids are likely to be septic, are blamed for activated sludge bulking. Onset of bulking following a rain which flushes out septic solids from the combined sewers after a prolonged dry period is common. Similar effects are reported when a concentrated supernatant liquor from digestion tanks is returned to the raw sewage (Omaha and Hackensack) and when the primary sedimentation tanks fail to retain completely the waste activated sludge solids discharged thereto at high rates (Omaha and Springfield).

4. Consistently overloaded plants are almost always operated under a condition of chronic bulking, a situation obviously beyond control of the operator. Wartime population increases together with boron wastes from citrus fruit packing industries has brought this condition at Pomona, Cal. Commenting on bulking experience at Lima, Smith states, "When an activated sludge plant is operated at full load under summer conditions, as the Lima plant was in 1942 for over 50 per cent of each day, bulking will occur." Many plants not now troubled with bulking will undoubtedly experience the problem as design loads are approached and exceeded in the future, unless plant expansion is accomplished in pace with increases in domestic sewage and industrial waste flows.

Wheeler at Chicago (Calumet) considers the infrequency of bulking at this plant to be due to the relatively low volatile content of the sewage received. At Pasadena, Allen has been unable to associate any specific causes to the sludge bulking which occurs at irregular intervals; however, relatively high temperatures such as prevail in California are generally believed to accelerate bulking.

It will be evident that continuously careful and vigilant attention to the control of mixed liquor solids, return sludge rates and air application will prevent many instances of bulking. Industrial waste survey and control will minimize cases resulting from such sources. In other cases bulking may be prevented by improvement in supernatant liquor quality or by alternate methods of disposal. At Hackensack, elimination of a heavy supernatant liquor, together with a higher mixed liquor solids level (1,600 p.p.m.) and improved dissolved oxygen control during aeration, have successfully prevented bulking for the past two years. Where shock loads from industries are likely to be received, it is desirable to have such knowledge early so that measures may be taken to prevent bulking. The industrial waste "slugs" received at Decatur, Ill., and Lancaster, Pa., are of such nature that pH determinations on the raw sewage at intervals during the day are regular procedure. An abrupt change in pH signals that a "slug" has arrived and enables adjustment in air supply or return sludge rate to be made before damage to the activated sludge takes place. Barton at Findlay and Adams at Tenafly use the

methylene blue stability test on samples of the primary effluent for the same purpose, immediate loss of color being taken as indication that air application and sludge return should be increased to meet a shock load. This determination is routine at 8-hour intervals at Findlay.

In the earliest stages of bulking, operators appear to be in general agreement that additional air application, increase in rate of sludge return and, if possible, reduction in the applied load to the aeration tanks, are the proper operating adjustments. Ahrens at Omaha supplements these controls with the return of plant effluent to the sewage entering the primary tanks during the low night flows, thus reducing detention periods and freshening the aeration influent sewage.

At five of the plants included in this review, *i.e.*, Lancaster, Lima, Mansfield, Tenafly and Wards Island, chlorination of the return sludge has been found efficacious in destroying the filamentous organisms, such as *Sphaerotilus*, which usually infest bulking activated sludge, as well as in reducing the high initial oxygen requirements of the sludge. Return sludge chlorination is relied on as a routine remedy for bulking at the above and many other plants although some instances have been reported in which the treatment was not completely successful. For best results, it appears that the treatment should be instituted as soon as bulking becomes imminent with the chlorine applied at carefully controlled rates.

Probably the best information available on return sludge chlorination comes from Lima, Ohio, where Smith has employed the method since 1934, from which experience it has been concluded that it is the only uniformly successful remedy for bulking in this heavily loaded plant. Application of chlorine to the return sludge is begun when the aerated mixed liquor settling test shows the sludge to occupy more than 20 per cent of the sample volume after one hour settling. In arriving at the optimum chlorine dosages, Smith has recognized the concentration of solids in the return sludge as an important factor and expresses the chlorine dosages on this basis. Since 1936, chlorination of the return sludge has been required 3 to 12 times a year, the dosages averaging about 8.5 p.p.m. chlorine for each per cent suspended solids in the return sludge and ranging from 3.9 p.p.m. to 14.9 p.p.m. for each per cent solids. These dosages represent an average of 6.5 p.p.m. and a range of 3.0 to 11.7 p.p.m. of chlorine on the basis of the volume of return sludge flow. From the Lima experience Smith concludes as follows:

"1. Return sludge chlorination for correction of bulking has been practiced at Lima for nine years with success.

"2. Chlorine should be used for correction of bulking only, not for prevention.

"3. The amounts observed at Lima to be required for quick results are not less than 6 p.p.m. based on return sludge flow or less than 8 p.p.m. for each per cent of solids in return sludge.

"4. Nearly complete recovery from bulking may be expected at Lima within seven days after the beginning of chlorination of return sludge, and recovery has been effected on many occasions after as few as three days' chlorination.

"5. With effective reliance upon chlorination as a corrective of bulking, power requirements for air compression may be reduced to the minimum, and the combination of the above considerations should result in marked economy of operation."

When bulking is beyond control, *i.e.*, application of the above remedies fails to bring about restoration of a properly conditioned activated sludge, most operators agree that all or part of the bulky sludge must be wasted and a new sludge developed. At Indianapolis, waste sludge is readily disposed of by discharge to lagoons, hence all of the bad sludge is wasted. Where sludge wasting and disposal facilities may be limited, however, it is not always possible to effect complete wastage of the bulked sludge in a reasonable length of time and a part of the original mixed liquor solids may be retained. Ahrens at Omaha wastes the mixed liquor solids to about half the desired concentration and uses an increased rate of sludge return while the new sludge develops. Anderson (Muskegon Heights) retains about 300 p.p.m. of the bulked mixed liquor solids when redeveloping an activated sludge even though he is not restricted in waste sludge disposition facilities. At Findlay, O., Barton notes marked improvement in the condition of the mixed liquor solids in 5 to 10 hours after purging of the final tank contents through the plant is commenced.

Edwards (Wards Island), Larson (Springfield) and Turner (Mansfield) refer to the benefits derived from a rain while sludge is bulking. This remedial effect is generally ascribed to the reduction of the volatile matter concentration in the sludge, resulting in better density and lower initial demand for oxygen.

Application to the mixed liquor of lime, copper sulfate and pulverized clay has been attempted as a corrective for bulking activated sludge but has not proven uniformly successful up to this time.

Other Operation Problems

Rising Sludge at Final Settling Tanks.—At almost half of the plants represented here, difficulty has been experienced at some time or another with the rising of large masses of the sludge to the surface of the final settling tank. At Fort Wayne, Hackensack, Pasadena and Springfield, the condition has been noted to occur when nitrification is high as is common when the sludge is over-aerated. The most common opinion on the cause of this condition is that the nitrates are reduced in the sludge blanket as the dissolved oxygen is depleted, resulting in the ebullition of nitrogen bubbles which carry the sludge masses to the surface. Correction is usually accomplished quickly by decreasing the air application. The plant at Hackensack appears to be particularly susceptible to this condition and the mixed liquor dissolved oxygen content must be held below 2.0 p.p.m. to avoid it. Bloodgood eliminates the condition by increasing the sewage load to the unit causing trouble, thus furnishing additional bacterial food. When increase in load is not feasible, he suggests that the mixed liquor solids be reduced.

Rising sludge masses may also occur with the onset of septicity in a final settling tank blanket of very dense sludge, as at Muskegon Heights, where reaeration of the return sludge is employed as the remedy. Smith at Lima increases the return rate and applies a fine spray of water at the tank surface to break up the sludge masses, on the rare occasions that the problem has been encountered.

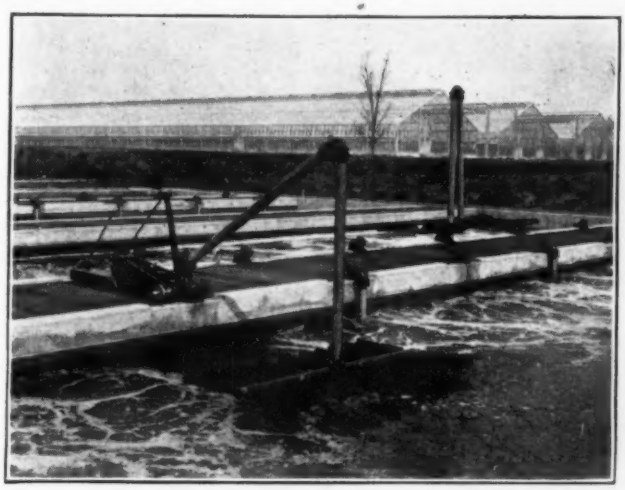


Fig. 5.—"Swing diffusers" raised for inspection and maintenance, Omaha, Neb.

Munroe at the York Township, Toronto, plant suggests that sludge rising due to septicity in hot weather may result from the failure of the sludge collectors to keep the tank bottom clean, directing attention to the desirability of care in maintaining proper adjustment of the plows or flights.

Oil and Grease.—In about a third of the plants contributing to this study, varying degrees of difficulty are reported to have resulted from the discharge of oils or grease to aeration units. Oils are usually received in "slugs" after accidental loss to the sewers or temporary breakdown of industrial separators. Grease is more likely to be a day-to-day problem since few industries provide adequate facilities and care in removing it from process wastes, particularly if the grease is in an emulsified state, difficult to separate.

Rapid and damaging reactions are reported to occur when a quantity of oil comes in contact with activated sludge, as experienced at Chicago Calumet, Fort Wayne, Hackensack and Omaha. In every case, air requirements were greatly increased and the clarifying and oxidizing capacity of the sludge immediately reduced, as evidenced by increases in the B.O.D. and suspended solids content of the plant effluent. Coating and impregnation of the activated sludge particles, interfering with the absorption of oxygen is believed to be the direct effect of the oil. At Fort Wayne, Brunner reports that a 3,000 gallon "shot" of fuel oil necessitated increase in air application from about 1.0 to 1.75 cu. ft. per gal. to hold 2.0 p.p.m. of mixed liquor dissolved oxygen. Receipt of 8,000 gallons of fuel oil at the Omaha plant completely destroyed the activated sludge, entailing a new start. Several discharges of a petroleum-base oil have been received at Hackensack and, although treatment efficiency is affected, the condition has been correctible by increased air application while the oil is present.

Grease may to some extent affect the activated sludge in a manner similar to oil but is believed to exert its greatest influence in the form of an organic overload. A combination of industrial oil wastes with grease solvent wastes constitutes a real problem at Muskegon Heights. At Elyria, Collier reports averages of 105, 33 and 3 p.p.m. of grease in the raw sewage primary effluent and final effluent, respectively, yet is more concerned with the grease disposal problem at the sludge digestion tanks than with the effect on the activated sludge. Adams at Tenafly states that determinations made several years ago reveal that the normal activated sludge at this plant contained about 20 per cent of ether-soluble grease but that attempts to correlate the grease content with the condition of the sludge were unsuccessful.

Chironomus Larvae.—In a few plants, a troublesome problem is created by the bloodworm or larvae of the *chironomus* fly. This insect has caused serious interference with operation of activated sludge units at Muskegon Heights and Findlay. Anderson (Muskegon Heights) furnishes an excellent commentary on the problem:

"The production of bloodworms in sewage is due primarily, I believe, to stale sewage and warm temperature. We have a considerable number of flat sewers and when the temperature of the sewage reaches about 70° F. the treatment plant usually becomes infested with bloodworms which have caused a great deal of difficulty with operation of the aeration plant.

"The worms form cocoons of sludge, about one inch in length by one-eighth inch diameter, which adhere to the walls of the tanks and finally break loose and float on the surface of the final settling tanks, due to entrained air or because the particles of sludge have become septic. The sludge may float in the original cocoon form or a very thin film of sludge may cover the entire tank surface. Also, small masses of sludge may rise to the surface causing very unsightly conditions and a loss of sludge. Invariably, during the period of infestation, the sludge is heavy, settles rapidly, and is in a semi-septic state.

"We finally reached the conclusion that the best remedy was to remove all of the sludge from the final settling tank sumps as rapidly as it was deposited. However, this required a return rate up to as high as 70 per cent and, when discharged to the entrance of the aeration unit, it shortened the aeration period and reduced efficiency. We then installed a sheet metal pipe from the return sludge chamber to a point about 25 feet from the discharge end of adjustable weirs so that the required portion of return activated sludge may be discharged to the first aeration tank with the remaining portion being discharged to the final aeration tank. We have four aeration tanks and larger amounts of air are applied at the first and last tanks during this method of operation. The method has prevented any sludge from floating on the final settling tanks during the past six years and apparently reduces the period of infestation to three to four weeks. Samples are collected for the laboratory and the rate of settling is watched closely, for when the period of infestation ceases the sludge index may rise rapidly and cause bulking. When the sludge index reached about 150 we return to the normal method of operating the aeration unit."

At Findlay, Barton describes the effect of *chironomidal* infestation as "devastating." Copper sulfate has been found efficacious in preventing the adult fly from laying eggs but is valueless after the eggs are deposited. After the larvae are present, practice at Findlay is to waste all of the infested sludge and start anew.

Maintenance of Air Diffusers

Among the most troublesome problems of physical maintenance of activated sludge plants is that of clogging and restoration of air diffusers. Diffuser clogging has become chronic in some plants after only a few months of operation; at others, no such difficulties have arisen in years. Among the latter are Pomona, Cal., where air diffuser tubes were used without being cleaned during a fifteen-year period; Springfield, Ill. (Fig. 3), where no clogging of plates has been experienced in almost fourteen years; and the plants at Findlay and Muskegon Heights which have been operating five years or more without experiencing diffuser clogging. Probably typical of average experience is that at Fort Wayne, which plant has been operating about two and a half years and where it is now necessary to replace the plates in one aeration tank and to institute a general schedule and procedure for restoring clogged plates. At Pasadena, Allen finds that annual cleaning of the plates in the older ridge-and-furrow tanks is required, usually after heavy rainy seasons, while some of the plates in the new spiral-flow tanks have not required cleaning in six years.

At some plants in which clogging is not a serious problem, a regular plate cleaning schedule is followed as a preventative. Harris at North Toronto drains the aeration tanks for plate cleaning operations once each year even though no appreciable increase in applied air pressure occurs in that interval. Diffuser plates at Omaha (in mixed liquor channels) and at Lancaster are occasionally "flushed" by the application of large quantities of air, this being the only attention required as yet in these relatively new plants.

Cause of Diffuser Clogging.—Although the direct cause of the diffuser clogging may not always be apparent, the following reported causes are typical of general experience:

1. Industrial wastes containing ferrous iron in sufficient concentration to form a hydrate as they are oxidized during aeration, which hydrate deposits on the top of the plate and penetrates into the surface pores. Clogging from this cause has been minimized at Chicago Calumet by diversion of pickling liquors from the sewers; such wastes in an average concentration of 65 p.p.m. total Fe in the settled sewage at Elyria create a serious clogging problem.
2. Organic growths which accumulate on the plate surface and restrict the pore openings, experienced at Indianapolis, Wards Island and Tenafly (only in old tanks in which the plates are of low permeability no trouble at more porous plates in new units).
3. Grease accumulations on top of plates, reported at Pasadena and Toronto.
4. Dirt and soot deposited on the underside of the plates by the applied air. Reported at Fort Wayne and Indianapolis. Recent examination at Fort Wayne also revealed an accumulation of paper fibers from the paper-cloth air filters.
5. Sand and silt impregnations at the top surface of the plates has caused trouble at Pasadena, Fort Wayne and Toronto.
6. Hard water scale is held responsible for the diffuser clogging encountered at Lima, Ohio.

Clogging of plates by activated sludge solids which subside to the bottom when the air supply may be interrupted by power failure or mechanical breakdown, is mentioned by several operators. When an aeration unit is to be removed from service for any reason, the application of air should be continued until the tank contents are drained to a level below the diffusers. Turner (Mansfield) and Adams (Tenafly) note that the diffuser plates clog more quickly when small quantities of air are being applied. Allen at Pasadena observes that the accumulation of grease deposits and silt at the plates increases rapidly when the plates become partially clogged.

Methods of Cleaning.—Diffuser cleaning procedures reported are summarized herewith:

Chicago Calumet—Ferrous iron deposits. Plates cleaned in place 2 to 3 times yearly. Washing and brushing followed by application of solution of equal parts water and sulfuric acid, to which sodium dichromate is added. Acid left in contact several hours, sometimes overnight. Second application given if clogging severe.

Elyria—Ferrous iron deposits. Plates cleaned in place annually. Deposits removed by application of hot flame which "spalls off" plate surface. Blow-torch used on silica plates, oxy-acetylene flame on carborundum.

Indianapolis—Organic growths, soot, dirt. Removable plates cleaned every two years. Plates are boiled in 6 per cent caustic solution for 5 hours, washed thoroughly and submerged in 10 per cent muriatic acid solution for 18 hours. No satisfactory method for cleaning plates grouted in place found as yet.

Wards Island—Organic growths and deposits. Plates cleaned in place every 1 to 2 years. Tanks drained, plates washed with hose, swept with deck brushes and allowed to dry (Fig. 4). Solution of 25 per cent caustic soda applied and left in contact for 24 hours. Caustic treatment repeated on plates in first pass. Plates put into operation without rinsing out caustic.

Hackensack—Organic deposits. Plates removed for cleaning annually. Soaked in 20 per cent caustic soda solution, rinsed freely and drained. Dipped into strong nitric acid solution and rinsed.

Mansfield—Organic deposits. Plates removed for cleaning every 2 years. Boiling and strong caustic solution followed by rinsing gives 96 per cent recovery of permeability.

North Toronto—Grease accumulations. Plates cleaned in place annually. Four holders at a time connected to low-pressure steam line and plate surfaces brushed vigorously with stiff-bristle brush. Thin, greasy scum removed thus.

Toronto—Plates cleaned in place twice yearly. Water jet at 110 pounds pressure with vigorous sweeping with street brooms, while plates subjected to normal air pressure, removes sand and silt. Grease accumulations removed by low pressure steam applications as at North Toronto.

Pasadena—Grease and silt. Plates in old ridge-and-furrow units cleaned annually. First washed in place with high pressure nozzle, followed by application of acid and rinsing. Treatment usually successful but if not, plates are replaced.

Rockville Center—Diffuser tubes cleaned in place weekly. Air valve on pipe to each diffusion unit closed and temporary hose connection made to city water supply. Flushing by water in this fashion has maintained tubes in good condition for eleven years. (Probably involves cross-connection to water supply, however.)

Lima—Hard water scale. Plates treated annually in place by application of weak muriatic acid solution.

Omaha—Chicago swing diffusers. Raising of diffuser units (Fig. 5) to enable them to be washed off with hose once a month, has sufficed during the first 18 months of operation of plant. Air pressure increase of about 0.5 lb. per sq. in. noted between cleanings.

When replacement of diffuser plates becomes necessary Allen (Pasadena) recommends that all plates in the same row or holder be changed at the same time. Use of a new plate in a holder containing old ones has been observed to disrupt the uniformity of air distribution because of the higher permeability of the new plate.

Waste Activated Sludge Disposal

Because of the high moisture content of waste activated sludge, its disposition almost always involves some difficulties which often influence control of the entire plant. Some problem associated with waste sludge disposal is reported at all but five of the plants represented here.

The most common method of effecting concentration of the waste activated sludge is by discharge to the raw sewage so that the waste solids are removed with the raw solids at the primary settling tanks. That this procedure is not without shortcomings is indicated by the fact that of twelve plants employing the method, only three fail to report some difficulty. Concentration of the waste activated sludge at the primary tanks at San Antonio has been found definitely unsatisfactory, probably due to the high temperatures which induce rapid septicity, and the high activated sludge index which prevails in that plant. At Fort Wayne, Muskegon Heights and Springfield, primary sedimentation efficiency is reduced when the waste sludge is light or bulking and some of the waste sludge solids pass on to the aeration tanks, imposing a recirculating load. Since increased waste is usually desirable under bulking conditions, inability to remove and concentrate the waste sludge is a serious limitation in the restoration of proper conditions at the activated sludge units. Lehmann (Hackensack), Brunner (Fort Wayne) and Larson (Springfield) emphasize the importance of frequent removal of the waste activated-raw sludge mixture from the primary tanks to avoid rising of sludge masses from the sludge hoppers. The air-lift bubbler device (Fig. 1) used at Fort Wayne for observation of sludge blanket elevations in the final settling tanks, has also been installed at the primary tanks so that excessive and overlong sludge accumulation can be avoided. At Lancaster, Mansfield and North Toronto, the waste activated-raw sludge mixture is high in moisture content, resulting in large quantities of digester supernatant as well as thin digested sludges. Alum is used to advantage in facilitating air drying of the thin digested sludge produced at North Toronto. Smith attributes the generally satisfactory removal and concentration of waste activated sludge in the primary tanks at Lima to the semi-automatic arrangement employed to control the rates of waste and return flow. To summarize this experience, it would appear that concentration of waste activated sludge at the primary tanks is reasonably satisfactory when the waste sludge is of low index, and that waste at low, uniform rates with frequent sludge removals from the primary tanks are highly desirable.

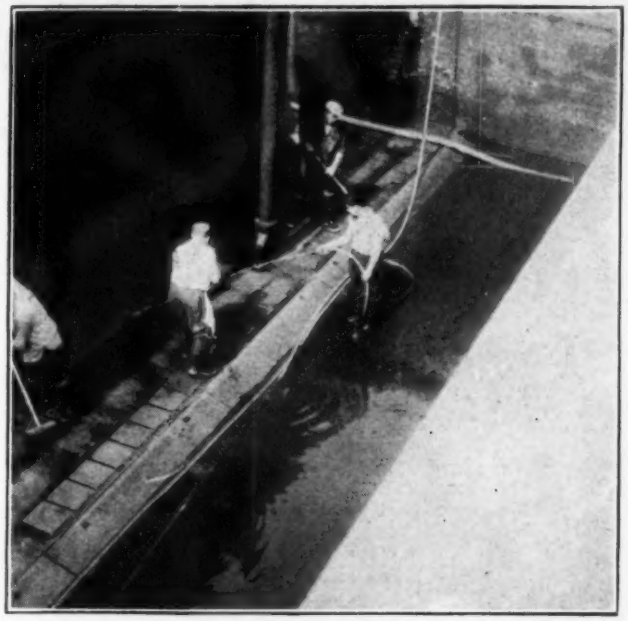


Fig. 5.—Cleaning diffuser plates at Wards Island plant, New York City

Separate decantation or concentration units are used at Rockville Centre before mixing the thickened waste sludge with raw sludge prior to digestion. Andersen reports no difficulties. The waste sludge is chlorinated at Wards Island to expedite concentration in the four final settling tanks used expressly for this purpose; concentration to 3 per cent solids is difficult, however. The concentrated sludge at Wards Island is pumped into tankers and disposed of at sea about 35 miles from the plant. Prompted by the need for sludge concentration at Findlay, Barton has conducted laboratory experiments on the thickening of the raw-waste activated sludge mixtures after dilution with digester supernatant liquor. One interesting but unexplained finding is that a 50 per cent water separation after settling occurs with a ratio of equal parts of supernatant and the mixed sludges, whereas a 40 per cent water separation is achieved when one part of supernatant is added to two parts of the sludge mixture. Plant scale facilities are not available at Findlay for further studies.

At Chicago Calumet, Tenafly and Toronto, the waste sludge is conditioned with chemicals and dewatered on vacuum filters. Adams at Tenafly finds that the character of the waste sludge exerts an appreciable influence on the dewatering operation; a light sludge giving poor filter yields while a heavy sludge will not cling properly at the bottom of the filter drum. The sludge index of the mixed liquor is adjusted to remedy these conditions.

The primary and waste activated sludges at Indianapolis are discharged to open lagoons for digestion and drying. The only problem as yet encountered is in bringing about removal of the dried sludge from the plant. About 25,000 to 35,000 cubic yards per year are sold and hauled away by local users but this is not quite up to the annual production.

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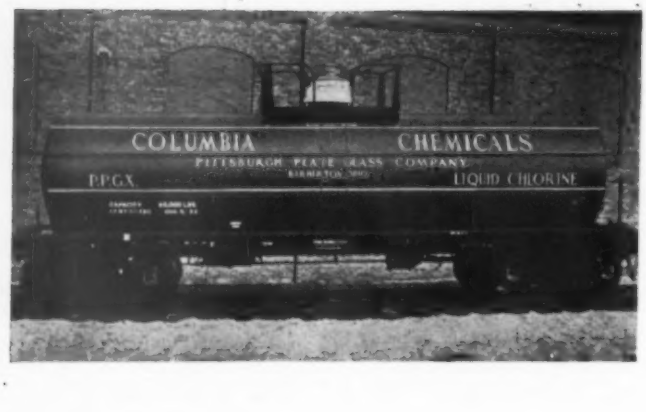

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PURGING AIR DIFFUSER PLATES WITH CHLORINE

By W. M. FRANKLIN, Superintendent
Water and Sewage Plant, Charlotte, North Carolina

The five aeration units at the Irwin Creek Sewage Treatment Plant, at Charlotte, N. C., are of the ridge and furrow type, equipped with diffuser plates. Manometers register the cubic feet of air per minute being delivered to each aeration unit. A master air-meter records the total quantity of air applied.

In the early summer of 1938 the diffuser plates in all the units became so badly clogged that it was impossible, even with two blowers in service, to get enough air through them to maintain proper aeration. All units were then cleaned out, as rapidly as they could be spared from service, and the diffuser plates scrubbed with muriatic acid. This had been the practice since the beginning of plant operation. All but two of the units responded reasonably well to this treatment. Units, No. 1 and No. 5, became clogged again after a few weeks operation. The acid cleaning was repeated in these two but with no better success. The normal average delivery of air per unit with one blower in operation is about 700 to 750 cubic feet per minute. The delivery of the diffusers in No. 5 unit was down to an average of 450 ft. with one blower in service, and with two blowers in parallel an average of 750 ft. could be maintained—(see Fig. 1). Since it was impossible to increase the air delivery in these two units by throttling the other three, and thus increasing the pressure of the air in the header feeding the diffusers, we were in something of a "mess."

At this time the plant load was heavy and the removal of one unit from service for a period long enough to empty and clean was extremely hazardous.

We decided to follow a suggestion previously made by L. H. Enslow of the Chlorine Institute. This suggestion was to add chlorine (as gas) to the air headers leading to the diffusers, with the idea that the chlorine would destroy algae growth in the plates, and might attack other clogging materials.

We first viewed this plan with alarm, fearing that the presence of chlorine gas in the air lines might cause corrosion, especially in the small feeder lines. Finally it was decided to try chlorine anyway. A tap was made in the header feeding No. 5 unit and chlorine fed into the air flow at the rate of about 17 lbs. per day.

In Fig. 1 the delivery of the diffusers in No. 5 aeration unit, in cubic feet of air per minute, has been plotted from August 22, 1938, through Oct. 9, 1938. Dotted lines indicate the period during which two blowers were operating in parallel, the solid lines indicating the period during which only one blower was in operation. Note that on Sept. 15 chlorine was fed for about four hours at the 17 lb. per day rate with two blowers operating. After the chlorine was cut off the two blowers remained in service the 18th. At this time one blower was removed from service and on the 19th the chlorine application was continued until the 150 lb. cylinder was exhausted on Sept. 25. The second blower was put on the line on the 24th with the idea that the increased velocity through the plates might help in opening up the pores. On the 30th normal operation was resumed with one blower.

Note the increase in air delivery during the period following the first "shot" of chlorine until the end of the curve on Oct. 9.

Actually, the chlorine brought about an increase of approximately 66% in air delivery with one blower in service and 53% with two blowers in service, as is shown by the curve. Needless to say we were so well pleased with the results that we immediately cleaned No. 1 unit with one cylinder of chlorine getting equally as gratifying results as was the case in the No. 5 unit.

At this date March 1, 1939, the air delivery of the diffusers in both Unit No. 5 and Unit No. 1 is about 750 cubic feet per minute and no detrimental effects from the application of chlorine have been observed.

It is our theory that the action of the chlorine not only cleaned the surface of the diffuser plate but also cleaned the pores *from the inside out,* removing organic matter from interior pores of the plate which could only otherwise be removed by a heat treatment, or long soaking in an acid bath.

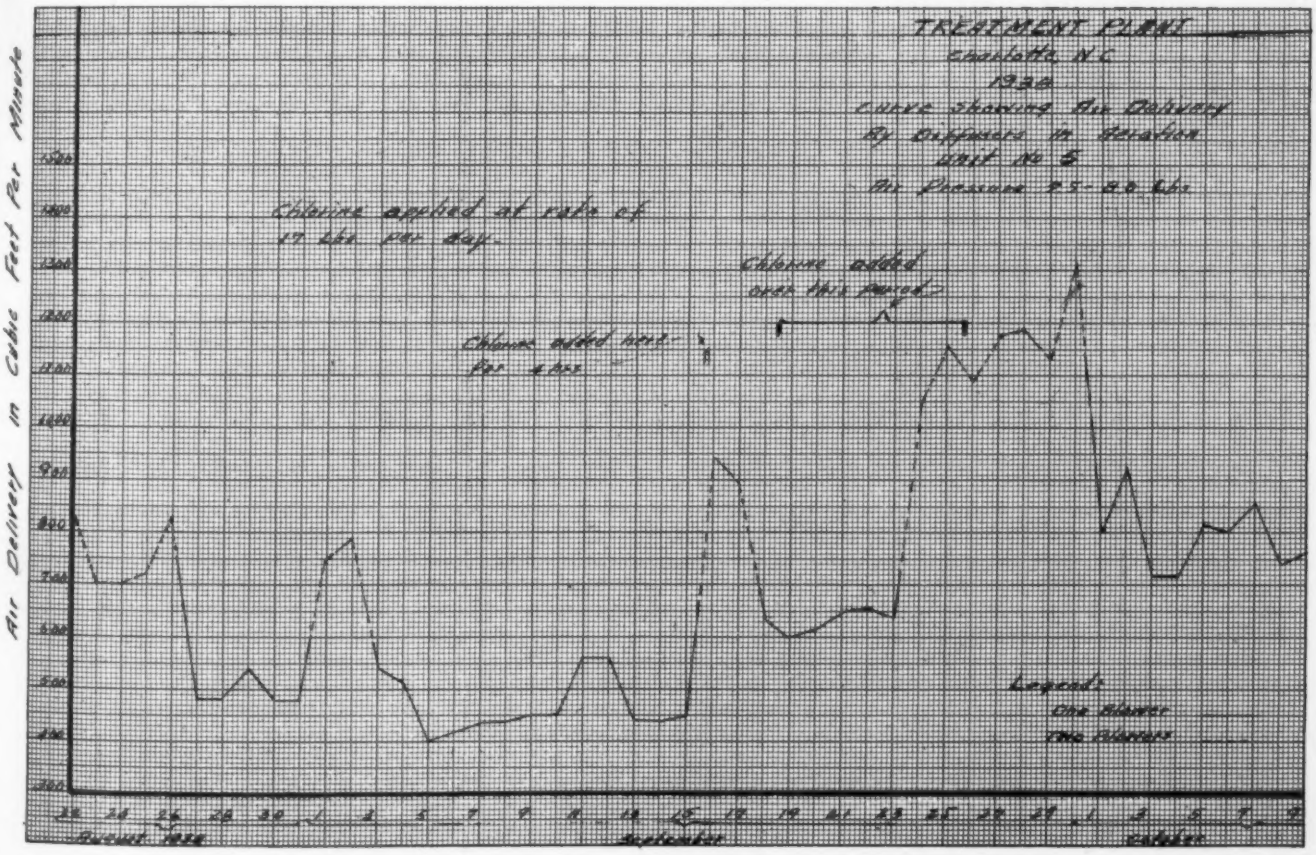

Fig. 1.—Graph Showing Change in Air Delivery Before and After Treatment of Plates With Chlorine Gas, in Situ

CLEANING AIR-DIFFUSION MEDIA

With Some of the Economic Considerations Involved

By JOHN J. WIRTS
Superintendent
Easterly Sewage Treatment Works, Cleveland, Ohio

THE PROBLEM of maintaining the porosity of air-diffusion plates and tubes used principally in conjunction with the activated sludge process and grease flotation and flocculation has been of growing concern to plant managers. The magnitude of the problem is increasing rapidly, due to two principal factors: (1) the widespread application of the activated sludge process during recent years; and (2) the increase of contributed industrial wastes incident to the war effort. Clogging is inherent with all diffusers required for efficient aeration of sewage. It follows, therefore, that such clogging must be accepted and that practical procedures must be developed to maintain efficient services. It is the purpose of this paper to discuss the need for and the process of cleaning diffusion media and to suggest a new scrubbing principle that has certain interesting possibilities.

Perhaps the best method of demonstrating the need for clean diffusion apparatus is by a dollars and cents comparison of air costs at increasing blower discharge pressures. It is the back pressure, created by the loss of head across the diffusers, that is solely responsible for higher costs of compressed air. In Table I the theoretical yearly cost of compressed air is computed for the Easterly Plant of Cleveland. The comparison is based on the use of 1.0 cubic foot of air per gallon of sewage, 6.7 mills per kilowatt hour for power, and a yearly sewage flow of 33,000 million gallons. On this basis an increase of one pound in blower discharge pressure can be evaluated to approximately $20,000. The cost of air per million gallons increased during the four year period from $2.68 to $3.56.

Table II shows the gradual rise, month by month, of the blower discharge pressure. The present rate of plate cleaning at this plant seems to be just enough to equalize the rate of clogging, roughly estimated at 0.4 pound per square inch increase in blower discharge pressure per year. Better still would be a gradual decrease in pressure from the built up average of 8.0 pounds per square inch for 1941 and 1942. For sewerage treatment plants in general it can be shown to be economically sound as a rule to begin a program of diffuser cleaning when the loss of head has increased 0.5 pound per square inch. This figure should be expected to vary from plant to plant, depending upon the cost of power at any particular plant. Cleaning cost should be more than offset by the decrease in power cost, otherwise there would be little advantage gained.

Fig. 1. Rubber Lined Acid-Soak and Rinse Tank for Diffuser Plate Cleaning
(The attendant wears rubber gloves and apron.)

Easterly Studies

Studies on diffuser plate cleaning was started in 1939 at the Easterly Treatment Works. Although this work began before there was any apparent need for cleaning, it was known that the character of sewage (high in iron salts and grease) was such that in due time the effects of clogging would become critical. Events subsequently have proved this assumption to be correct. Notable increases in blower discharge pressures were observed during the year 1940. Fortunately the plant was designed with the Burger removable cast aluminum plate manifolds, which made the clogged diffuser plates readily accessible for experimental purposes.

In the course of these studies, extensively reported in the *Sewage Works Journal*,[1] hundreds of plates were treated with various solutions, such as caustic soda, gasoline, muriatic acid, nitric acid and chromic acid. Previous investigators[2, 3] have been limited principally to the use of a loss of head measurement on fixed diffusers; these investigators being unable to accurately report the percentage recovery in porosity by treating procedures.

TABLE I—RELATION OF BLOWER DISCHARGE PRESSURE TO COST OF AIR

Year	Discharge Press. Lbs. per Sq. In.	K.W.H. Required per M. Cu. Ft. Air	K.W.H. Cost per M.G.	Yearly Cost[1]
1939	6.8	400	$2.68	$ 88,440
1940	7.1	463	3.10	102,300
1941	8.0	540	3.62	119,460
1942	8.0	531	3.56	117,480

TABLE II—BLOWER DISCHARGE PRESSURE
(Pounds per Square Inch)

	1939	1940	1941	1942
January	6.8	6.9	7.3	7.9
February	6.5	6.8	**	8.1
March	6.5	6.8	8.1	8.0
April	6.8	7.2	8.1	8.1
May	6.8	7.3	7.7	7.8
June	6.8	7.4	8.1	8.0
July	6.9	6.9	7.9	7.9
August	6.9	6.9	7.9	7.9
September	6.8	7.1	7.9	7.9
October	6.8	7.2	8.0	7.9
November	6.8	7.3	7.8	8.1
December	6.8	7.4	7.9	8.0
Average	6.8	7.1	8.0	8.0

**Plant out of operation part of month, omitted from average calculation.

The standard of comparison of rating of diffuser plates is permeability, which is defined as the number of cubic feet of air at 70° F. and 10 to 25 per cent relative humidity, that will pass through 1 square foot of diffuser area to the atmosphere, under a differential pressure through the diffuser equivalent to 2 inches of water when it is tested dry in a room maintained at a temperature of 70° and a relative humidity between 30 and 50 per cent. A precise determination of this value requires elaborate control of conditions and equipment. However, a more simplified procedure has been developed which has proved satisfactory for comparative purposes in testing plates.

An apparatus for permeability measurement was constructed

[1]Based on 1.0 cu. ft. of air per gallon of sewage, 6.7 mills per K.W.H. and yearly sewage flow of 33,000 M.G.
Note: Actual 1942 cost of power for blowers was $92,393 due to a rate reduction of 1.3 mills per K.W.H. by change in power source from a private power company to the Municipal Power Division.

after the type described by Beck.[2] It consists merely of a metal box for tightly holding the plate to be tested, an orifice meter for measurement of the rate of flow of air through the plate, and a draft manometer for measurement of pressure under the plate—i.e., the differential. The average test permeability of thirteen new diffusers was within one per cent of the permeability rated by the manufacturer. The maximum difference between test permeability and rated permeability for one plate was less than four per cent. In no case were air temperature and barometric pressure corrections applied. Relative humidity varied from 40 to 80 per cent with very little effect on the observed permeability. Damp or rainy days were avoided, as suggested by W. E. Holand.[3]

The functioning of the permeability apparatus should be checked by first testing with one or more reference plates of known permeability. Should the ratings not be normal, the apparatus should be checked for leaks. If there are no leaks the tests should be delayed until weather conditions are satisfactory.

Rubber gloves, rubber aprons and boots are provided the attendants for additional protection against chromic acid poisoning and strong caustic burns.

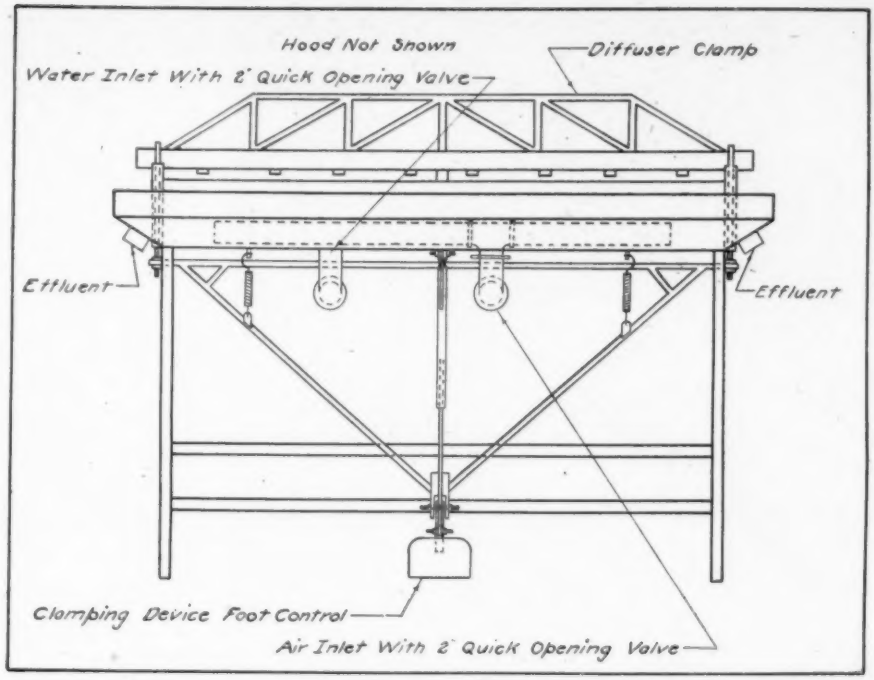

Fig. 2. Front View of Air-Water Wash Scrubbing Machine—Four Plate Capacity

Cleaning Equipment and Procedure

Twenty gallon crocks were provided for treating the diffusers, and a cylindrical rubber-lined steel soaking tank, as shown in Figure 1. The soaking tank was provided with water connections and a drain. Supports made of ⅜-inch rod covered with rubber tubing were hung in several of the crocks to hold the plates while the cleaning agent drained out after the treating period and prior to washing. The rubber-lined tank served as a storage tank for the drained, acid-soaking plates before the plates were transferred to the internal scrubbing machine (Figure 2), to be described later.

The method of cleaning consisted of three steps: (1) soaking the plates for several hours in a cleaning agent consisting of a 2 per cent solution of sodium dichromate in sulphuric acid, (2) allowing the cleaning agent to drain out of the plate, and finally (3) subjecting the plates to a thorough scrubbing with compressed air and water mixture.

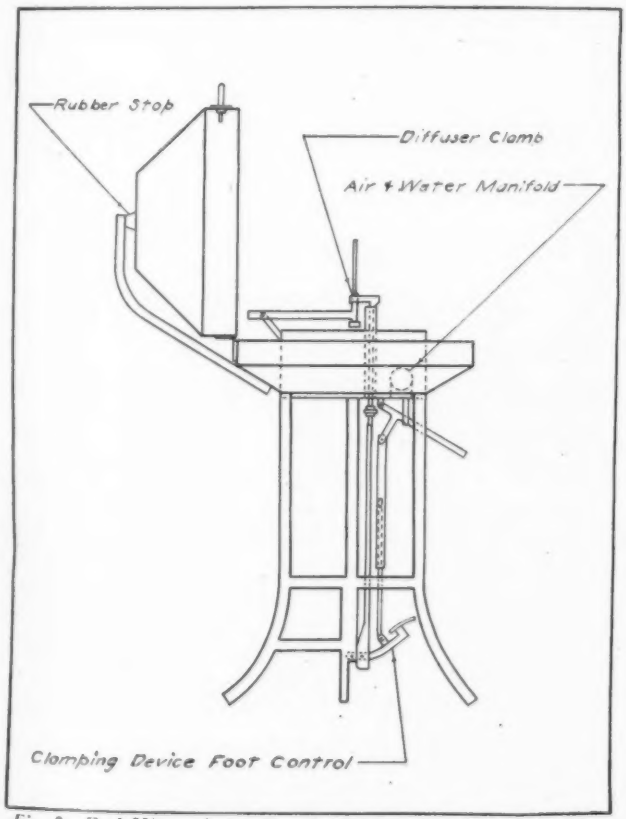

Fig. 3. End View of the Cleveland Plate Scrubbing Machine

Prior to development of the scrubbing machine it was ncessary to rinse the plates in as many as six baths of water, in order to remove the bulk of the cleaning solution. Even with this practice some of the agents remained inside the pores of the diffusers, with the result that on batches of 1,200 plates the average percentage of recovery of porosity was between 70 and 75, as determined by the permeability apparatus. Experience with these plates indicated that the reduction of head loss was satisfactory, but upon a second cleaning, following a year of service in the aeration tanks, the residue remaining from the original cleaning was very difficult to remove. Since the clogging of the diffusers is not limited to the top surface, but penetrates into the interstices, it is essential that the interior of the diffuser be freed of all deposits, if the life of the diffuser is to be prolonged. The combination of compressed air and water was selected as the most readily available agents to remove the deposits.

The Internal Scrubbing Device

The machine sketched in Figures 2 and 3 and pictured in Figures 4 and 5 provides holders for four 12 in. by 12 in. by 1 in. standard diffuser plates, which are firmly held down by the foot control clamping device. Two 2-inch quick opening valves allow water, air, or both, to enter the manifold beneath the plates. The water is taken from a line under 70 pounds per square inch pressure and the air is from an air main operating at 8 pounds per square inch pressure. The duration of the scrubbing period is about one minute. During that time the valves are in an open position, forcing the mixture of water and air up through the diffusers in a violent manner. The wash water spills into the effluent trough and then to waste. A sheet metal hood shown in Figure 4 is hinged to the rear of the machine and folds down, enclosing the diffusers. The purpose of the hood is to protect the operator from acid spray.

Rubber gloves, rubber aprons and boots are provided the attendants for additional protection against chromic acid poisoning and strong caustic burns.

The operator easily judges the time necessary for proper scrubbing by the uniform appearance of air bubbles (Figure 5). At the proper moment the quick opening valves are closed and the clamp released. The completely cleaned plates are then ready for service in the aeration tanks.

During the year 1942, 4,800 diffusers were treated with a 2 per cent solution of sodium dichromate in sulphuric acid. After machine scrubbing, these were found to be within 90 per cent of their original porosity. Table III gives the typical results of cleaning an aeration tank containing 1,200 diffusers. Five batches of six plates were selected as representative. Their permeabilities when new varied from 39 to 43. The overall recovery after cleaning averaged 91 per cent. Similar results were obtained for tested plates from other aeration tanks.

Fig. 4. The Plate Scrubber Being Loaded
(Ease in operation is provided by arrangement of clamping device in open position and quick opening water and air valve.)

TABLE III

TESTED PLATES FROM AERATION TANK No. 15 AFTER CLEANING			
No of Plates Tested	Rated Perm. (New)	Permeability After Treatment	Per Cent Recovery
6	39	36	92
6	40	36	90
6	41	37	90
6	42	38	90
6	43	40	93
Ave.... 6	41	37.4	91

A deposit of fine silt is found in the effluent trough of the machine after several hours of service. Quantitative analysis of this deposit showed a silica content of 70 per cent on a dry basis, the remaining 30 per cent consisting of a combination of aluminum and iron oxides. Although this deposit is in quantity very small per plate, its presence is difficult to explain. The silica content was identified as rounded grains of sand and the aluminum oxide consisted of very small particles of the diffuser plate. The iron oxide was that portion of insoluble iron that remained after the acid bath. It is believed that the activated sludge carries the silt referred to previously, and under certain conditions this silt is deposited in the pores of the plates, together with accompanying solids.

The unit cost of cleaning diffusers for the year 1942 was estimated at 45 cents per plate. Approximately 36 cents of this amount is charged against the labor in handling, that is, the labor of removing the plates from an aeration tank, chemically treating, machine scrubbing and replacing in the aeration tank. Sulphuric acid, dichromate of soda, caustic soda (when necessary), and miscellaneous items were estimated at 9 cents per plate.

Discussion and Conclusion

The permeability apparatus as described is a very useful and necessary device in developing cleaning procedures. The necessary tests for measuring the results can quickly be run on the permeability apparatus without elaborate corrections for humidity and temperature.

Fig. 5. The Plate Scrubber in Operation at Partial Rate with Spatter Hood Raised
Note the clamping bar locked in place by the quick-trip foot pedal. Operator is holding air-water mix valve partially open. Uniformity of bubbling constitutes the check-up on porosity recovery. This observation follows the high pressure air-water wash.

In routine plate cleaning, the 2-per cent dichromate solution in sulphuric acid is recommended. In certain cases in which grease is the principal clogging material, a strong caustic solution can be used first, then followed by the dichromate solution.

The use of compressed air and water in connection with internal scrubbing practically restores the diffusers to their original porosity. This is particularly true on the second or third times that the diffusers are cleaned, because residual clogging material is removed each time after a service period and is not allowed to build up inside the diffuser plates. Merely washing out the plates by a stream of water or by immersion in water is not sufficient to remove all of the clogging material and to restore the diffuser plate porosity.

It is sound economy to clean diffusers when the blower discharge pressure increase equals one-half pound per square inch.

It has been demonstrated that aluminum oxide ("Aloxite") diffusers can be economically removed from the Burger type aluminum holders, cleaned and returned on a full plant-scale basis at an overall profit in power savings.

The cost of labor in handling the diffusers is roughly 80 per cent of the total cost of cleaning operations, which is 45 cents per unit of one plate.

The development of an apparatus utilizing the principle of pressure scrubbing, that could be used on fixed diffusers, with suitable solvents, would eliminate much of the labor cost which is principally for removal and return of the plates. Such an apparatus, if made portable, would prove of almost universal use in plants using diffused air.

References

(1) Willard F. Schade and John J. Wirts, Diffuser Plate Cleaning Versus Compressed Air Cost—*Sewage Works Journal* 14, 81-96 (January 1942).

(2) A. J. Beck, Diffuser Plate Studies—*Sewage Works Journal* 8, 22-37 (January 1936).

(3) W. E. Howland, Discussion of paper "Diffuser Plate Studies"—*Sewage Works Journal* 8, 485-488 (May 1936).

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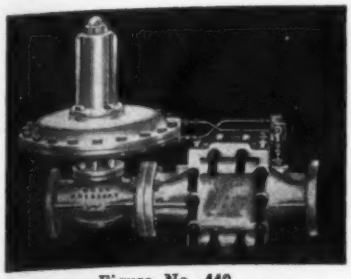

Figure No. 440

Sizes.	2"	2½"	3"	4"	6"
Sh. wt..	125	140	160	200	260

← THE NEW "VAREC" *Approved* PRESSURE RELIEF AND FLAME TRAP ASSEMBLY

Unit consists of Diaphragm-operated Regulator, Flame Trap, and Thermal Shutoff Valve. Maintains a predetermined back pressure, passing surplus gas to Burner. Stops flame propagation. Patented telescopic flame trap element simplifies inspection and maintenance. Listed by the Underwriters' Laboratories for vent lines in oil tanks.

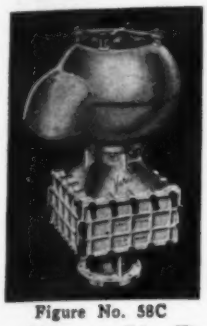

Figure No. 58C

"VAREC" *Approved* PRESSURE RELIEF AND VACUUM BREAKER VALVE WITH ←FLAME ARRESTER

Installed on digesters and gas holder domes, it affords emergency Pressure and Vacuum Relief and prevents flame entrance from atmospheric disturbances. Equipped with extensible Flame Arresting element for easy inspection and maintenance. Pure aluminum. Non-corrosive. Listed by the Underwriters' Laboratories for Vent Lines in oil tanks. Sizes 2" to 10".

Sizes	2"	3"	4"	6"
Sh. wt.	70	105	160	225

"VAREC" *Approved* WASTE GAS BURNERS——→

Installed wherever disposal of surplus gas is a problem. Unit has adjustable air intake in the venturi tube, pilot valve adjustable from outside. Long, heavy cast iron draft stack insures proper draft and complete combustion.

Sizes	2"	3"	4"
Sh. wt.	450	480	500

Figure No. 236

Figure No. 450

"VAREC" *Approved* FLAME TRAP ASSEMBLY

Flame Trap and Thermal Shutoff Valve. Unit self-contained, simple, foolproof. Installed in all gas lines supplying gas utilization equipment. No expensive fitting-up necessary. Arrests flame propagation. Easy inspection and maintenance. Aluminum and stainless steel. Non-corrosive. Flame Trap Element listed by Underwriters' Laboratories for vent lines in oil tanks.

Sizes	2"	2½"	3"	4"	6"
Sh. wt...	90	100	115	150	200

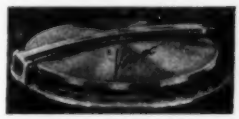

Figure No. 220A

"VREC" *Approved* MANHOLE COVERS

Installed on digester and gas holder domes, affords quick and easy access. Has square, graphite-impregnated, fire proof gasket. Nonsparking. Gas-tight.

Sizes	18"	20"
Sh. wt.	100	110

Figure No. 51A

"VAREC" *Approved* FLAME CHECK

Acid resisting. Union type fitting. Positive flame stop for small lines. Has five 40-mesh fire screens. Easy inspection and maintenance.

Sizes	½"	¾"	1"
Sh. wt.	10	10	10

Figure No. 216A

"VAREC" *Approved* MANOMETERS

Single or Triple tube. Open or push-button control types. Accurate. Aluminum housing. Bronze fittings. Pyrex glass. Automatic—Fireproof—Safe. Sizes 6" to 36".

Sizes	9"	12"	15"
Sh. wt. 16	18	20	

Figure No. 387

"VAREC" *Approved* SENSITIVE PRESSURE (REDUCING) REGULATOR SINGLE PORT

Maintains upstream or downstream pressure to within 0.5" of water of predetermined pressure. Positive Shutoff. Aluminum body. Throttling type inner valve. 18-8 stainless steel trim. Sizes 2" to 6".

Sizes .	2"	2½"	3"	4"
Sh. wt.	110	115	140	175

Figure No. 211A

"VAREC" *Approved* BACK PRESSURE (REDUCING) CHECK VALVE

Installed in relatively low pressure gas lines. Prevents back-flow through meters. Non-chattering, non-pulsating, non-corrosive, non-sparking.

2"	3"	4"	6"
20	35	70	125

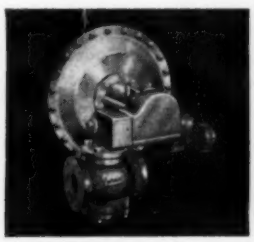

Figure No. 187

"VAREC" *Approved* SUPER SENSITIVE PRESSURE (REDUCING) REGULATOR DOUBLE PORT

Maintains upstream or downstream pressure to within 0.2" of water of predetermined pressure. Standard working parts 18-8 stainless steel with synthetic rubber diaphragm. Non-corrosive. Sizes ¼" to 10".

2"	2¼"	3"	4"	6"
190	200	233	260	350

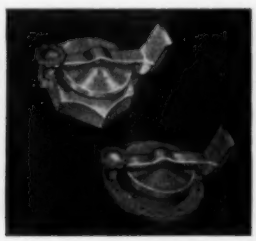

Figure Nos. 48 and 42A

"VAREC" *Approved* SAMPLING HATCH COVERS

For use on digester domes. Available in several combinations of materials. Non-corrosive, gas-tight, self-closing, spark-proof. Figure 42A Flanged and Figure 48 Screwed.

4"	6"	8"	10"
12	17	23	27

Figure No. 232D

"VAREC" *Approved* SEDIMENT TRAP AND CONDENSATE DRIP TRAP ASSEMBLY

Cast iron construction. 18-8 stainless steel working parts. Hand operated or automatic. Sizes 2"-2½"-3"-4".

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- Pre-Aerators and Grease Removers
- Laundry and Trade Wastes Treaters
- Air Diffusion Equipment
- Flush-Tank Siphons and Regulators
- Condensate Drip Traps
- Jointite Sewer Joint Compound
- Rotary Distributors
- Sprinkling Filter Nozzles
- Supernatant Treaters
- Twin Tank Controls
- Alternating Siphons
- Sewage Siphons
- Tray Clarifiers
- Sludge Pumps
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P.F.T. FLOATING COVERS

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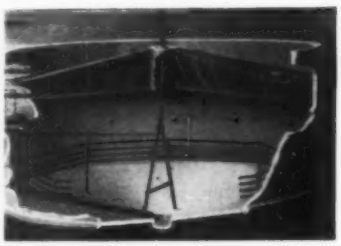


A positive means of removing the most desirable supernatant liquor at a slow, continuous rate from any type of digestion tank, regardless of location of supernatant in the tank. A slotted tube holds back liquid containing excessive solids; lets through only clearest supernatant. Readily installed. Bulletin 143.

P.F.T. ROTARY DISTRIBUTORS

Provide a practical, efficient unit for dosing sewage to filter medium, in minimum area and with minimum piping. Operate at minimum head, frequently eliminating pumping. Features include patented non-clogging spreader jets that assure full, even coverage of the filter bed; triple valves and a positive mercury seal. Bulletin No. 213.

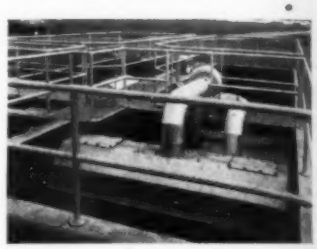
P.F.T. SPRINKLING FILTERS

P.F.T. has available several efficient types of circular spray sewage nozzles for application to the risers in sprinkling filter beds. Easy to install and clean. Designed to minimize clogging, and afford uniform distribution. Detailed in Data Book No. 130.

P.F.T. CLARIFIERS

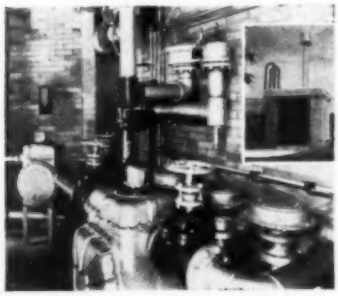
Designed to effect the continuous rapid separation of solids and liquids and the immediate removal of the clarified effluent. Consists of a series of trays or floors, one above the other, in effect a series of settling stages in a single tank. Bulletin No. 210.

P.F.T. SUPERNATANT LIQUOR TREATER



Essentially an aerator settling tank unit which returns to the head of the plant a treated effluent which will not cause operating difficulties. Bulletin 142. P.F.T. Pre-Treater of Laundry and Trade Wastes is a combination aerator-settler unit which reduces grease content, suspended solids and B.O.D. Bulletin 141. P.F.T. Atomizing Type Aerator for Pre-Aeration and Grease Removal consists of a surface chamber to which a vacuum is applied as a means of mixing atomized liquids and solids with a large volume of free air. Unit is mounted in a small section of the primary clarifier. Bulletin 140.

P.F.T. SLUDGE GAS CONTROL EQUIPMENT



Consists of Flame Traps, waste gas pressure relief flame traps, waste gas burners, pressure gauges and other boiler room and accessory equipment designed to eliminate explosion hazards and to insure constant pressures. P.F.T. Flame Traps have renewable elements which permit passage of gas but not flames. Valve in line is closed when heat is sufficent to melt fusible plug. All described in Bulletin 121-A.

PRINCIPLES OF POWER GENERATION WITH SEWAGE-GAS ENGINES

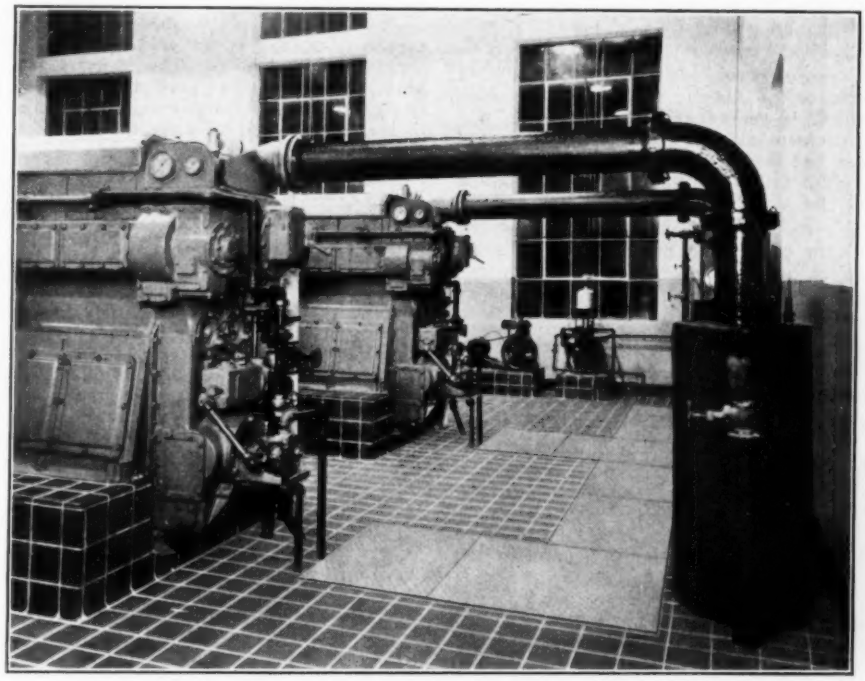
By NORMAN C. WITTWER

Consulting Engineer, Trenton, N. J. (Former Supervising Engineer, Rahway, N. J., Sewage Treatment Works)

Many interesting accounts of sewage-gas engine power generating installations have been published in the engineering literature during the past several years. Several of these, particularly the articles of Walraven (1) and Sperry (2), in WATER WORKS & SEWERAGE and *Sewage Works Journal* have been outstanding in the technical thoroughness with which the authors discussed their experiences with this new and valuable adjunct to sewage treatment.

The writer has recently had occasion to make a comprehensive study of the feasibility of power generation with sewage-gas engines for the Sewage Treatment Works of the Rahway Valley Joint Meeting. The results of this study indicate that a very substantial saving in power costs is possible by the substitution of gas-engine generator sets for the present public utility power. Our current annual power bill is approximately $5,700.00, which covers cost of pumping all sewage entering the plant, power for all auxiliary pumps and mechanical equipment, and lighting.

It should be pointed out that the only justification for making a capital expenditure for power generating equipment to supplant outside power service must lie in the *net* annual savings in power costs which may be derived. The considerations for or against such an installation must be purely financial, as the self-generation of power will not add to, or detract from general sewage plant operation, or the results to be obtained from the treatment processes.



Twin 150 H.P. Cooper-Bessemer Engine-Generator Sets for Durham, N. C. Note waste heat boilers on right.

Arrangements Possible

Many arrangements are possible by reason of which the installation of sewage-gas engines may prove to be desirable. Some are as follows:

1. Engines direct-connected to sewage pumps where all or part of the plant flow is pumped.
2. Engines direct-connected to blowers used for aerating sewage.
3. Engines direct-connected to generators for generation of all or part of the electric power required.
4. Engines direct-connected to miscellaneous items of mechanical equipment.

This article will present the technical and economic phases of a complete power-generation plant designed to provide power for *all* the operating requirements of the Rahway Valley Sewage Treatment Works. While the Rahway Plant is a primary treatment plant having a capacity of 25 mgd, the type or size of plant does not in itself control the economics of sewage-gas power production. A number of factors influence the problem, and each should be thoroughly studied. They are as follows:

1. Experience at other sewage treatment plants where sewage gas power is being used.
2. Power requirements for the service desired—average and peak loadings.
3. Size and type of generating units required.
4. Standby power service.
5. Quantity and dependability of gas supply as compared to the average and peak power requirements.
6. Heat recovery for the heating of digestion tanks and buildings.
7. Probable first cost.
8. Annual interest and amortization charges.
9. Operating and maintenance costs.
10. Annual savings, if any, as compared to the present power costs.

Experience at Other Sewage Treatment Plants

It was first thought advisable to investigate the experience at other sewage treatment plants where gas engines are in use. Accordingly, questionnaires were sent to a number of sewage treatment plants which have been using sewage-gas power over varying periods of time. The information obtained from these questionnaires is tabulated in Table 1, and may be summarized as follows:

1. Three plants from which replies were received were larger than our plant, ten were smaller.
2. All showed a net annual savings. Some indicated that interest and depreciation were first charged off; the others did not clearly stipulate.
3. The annual cost of repairs as compared to power production in most cases is very low.
4. The annual cost of lubricating oil in most cases is very low.
5. In most cases, a statement was made to the effect that the engines were operated by the regular force, with no additional men.
6. Each reply indicated that sewage-gas generation of power is satisfactory and practical.

Power Requirements

The power requirements for a new plant must be estimated, but for a plant in operation with a back-log of operating records,

the present and probable future requirements can be determined with a fair degree of accuracy.

By an examination of the first three columns of Table 2 under the heading "Hourly Rates of Power Consumption," it can be seen that the hourly power demand during an average day for the Rahway Valley Plant approximated 40 KWH during the first ten months of 1938. The hourly average of a maximum day during this period was 114 KWH, while for a minimum day it was 23 KWH. Temporary demands higher than 114 KWH have been recorded on the local power company's demand chart, the highest being 124 KWH during a heavy storm in September. Such extreme peak demands, although not frequent, do occur occasionally.

From these records, the folowing power requirements were determined:

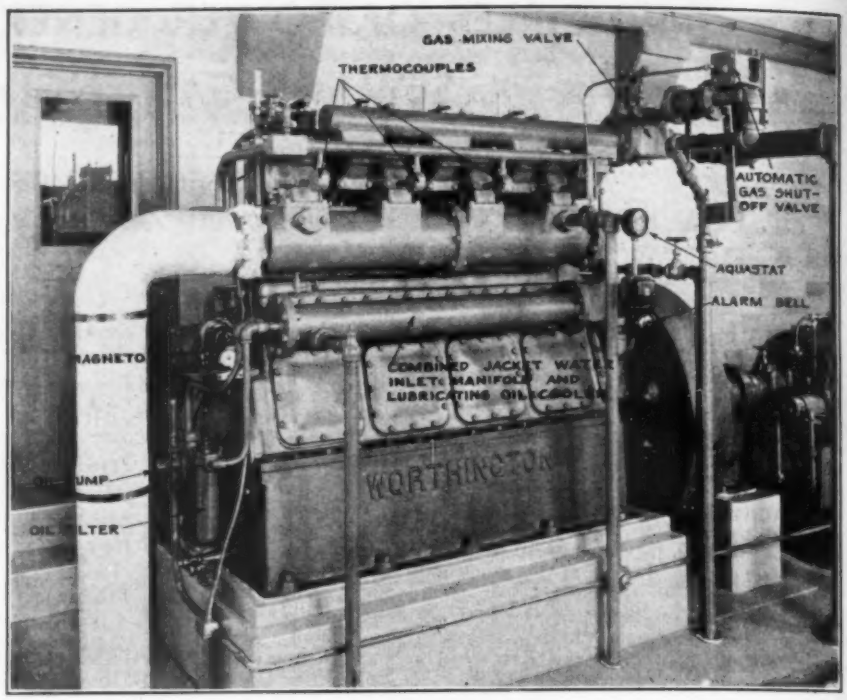
Average	40 KWH
Moderate Peak	99 KWH
Extreme Peak	124 KWH

A generating plant to take care of the above loadings will be as follows:

One 60 KW generator set to provide power for average demands, with sufficient reserve power for minor fluctuations.

One 60 KW generator set to serve as alternate to the first set, and to provide the additional power required for the peak demands.

Note:—Both generators operating in parallel will generate 120 KWH, and will easily stand the temporary overloading required to produce 125 KWH.



Worthington 120 H.P. Engine at Ann Arbor, Mich. Direct Connected to Blower

Some form of standby power service is always desirable. If the charges are within reason, an outside power company connection is the most practical. If such charges are too high, and they usually are, an arrangement may be made to use the local gas company's gas in case the supply of sewage gas fails. The scheme has proved entirely feasible and economical at existing plants.

If gasoline is to be used, a carburetor should be provided on the engine by means of which the engine may be operated as a gasoline engine. In the case of the Rahway Valley Plant, it is intended to cut off the local power company entirely and to use gasoline as the auxiliary fuel to serve as a standby.

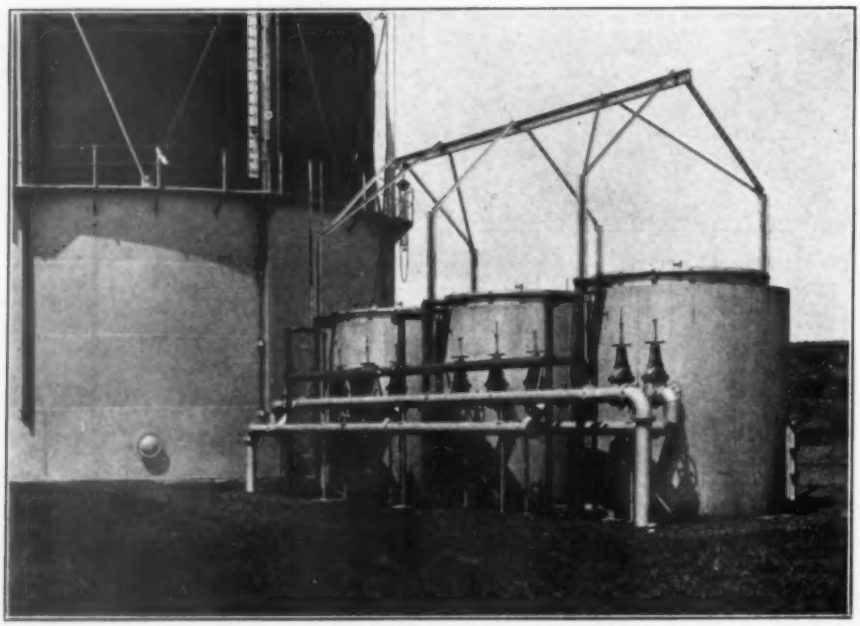
Selection of the Engine

The More Important Considerations

Many gas engines are on the market, some of which have been especially adapted to the use of digester gas as a fuel. The most serviceable type is the heavy-duty, slow-speed engine. Such engines are built to run continuously for a number of years with low cost of repairs and maintenance, and embody the standards of construction and the principal features of the heavy-duty Diesel engine.

Some sewage treatment plants have installed the lighter-weight, higher-speed automotive type of gas engine which is less expensive in first cost. However, experience has proven that in general these engines cannot be subjected to continuous service over protracted periods of time without high maintenance costs. In addition, their total useful life is much shorter than that of the heavy-duty engine, so that in the long run, the heavy-duty engine may be expected to prove the more economical type.

The special features to be considered in choice of engines are those involving long life and low maintenance costs. Valve-in-head engines are preferable in the smaller sizes. In the larger sizes, valves should be in removable cages, or should be otherwise easily removable for convenience in inspection and grinding of valves. Renewable valve-seat inserts should be provided for the exhaust valves, preferably of some high grade heat resisting metal such as "Stellite."



Koppers Gas Purifiers and Gas Holder at Peoria, Ill.

An engine of unit-block frame type, bolted direct to the engine base, is preferred. Each cylinder head should be a separate casting, and renewable cylinder liners of a high strength material should be provided so that wear in a cylinder will require the replacement of a liner only, rather than a complete cylinder. It was found at the Coney Island (N. Y.) Plant that the liners can stand three reborings before replacement is necessary.

The main bearings should be lined with a high-grade anti-friction metal, and should be fitted so that they can be removed without disturbing the crankshaft. Easy access should also be provided to the connecting-rod bearings. Water jacket space should be accessible for cleaning through ample covered openings inside of the frame.

When the engine is direct-connected to a generator, a fly wheel should be mounted on the drive end of the crank shaft. It should be dynamically balanced and have sufficient inertia to insure the degree of uniform rotation required for generator operation. A governor should be provided which will satis-

factorily control the speed of the engine to the limits required for the guaranteed operation of the generator.

The customary oil filter and air filter should also form a part of the installation. Safety devices are also very desirable, such as an electric alarm and automatic shutdown system, to protect the engine against low lubricating oil pressure and excessive jacket water temperature.

The desirable features *not* customarily found on automotive types of engines may be summarized as follows:

1. Unit-block frame bolted direct to engine base.
2. Cylinder heads as separate castings.
3. Renewable cylinder liners.
4. Renewable valve-seat inserts for exhaust valves.
5. Valves readily removable.
6. Main bearings mounted in engine base.
7. Main bearings readily removable.
8. Water jacket space accessible for cleaning.
9. Flywheel, if engine drives a generator.
10. Governor to control engine speed.
11. Safety devices.
12. Piston speed not to exceed 1000 feet per minutes.
13. Brake mean effective pressure not to exceed 70 pounds per square inch.

Quantity, Quality and Dependability of Sludge Gas

The evolution and production of sewage gas is normally a continuous and uninterrupted process, resulting from the biological decomposition of sewage sludge in digestion tanks. During this process a portion of the volatile organic matter in the sludge is converted into a combustible gaseous mixture which is approximately

Methane	64%
Carbon Dioxide	30%
Nitrogen	5%
Hydrogen Sulphide	Trace
Other Gases	1%

Weekly analyses of the gas at Rahway have been run since the plant was placed under operation. From these analyses (made with a Bureau of Mines Gas Analysis Apparatus) the average heat value of the gas has been found to be about 650 Btu. per cubic foot. This is slightly higher than commercial gas, which runs about 550 Btu. per cubic foot. In an internal combustion engine, about 10% of this heat is not available, this being the heat of vaporization. Thus the dependable minimum heat value of the gas becomes 575 to 600 Btu. per cubic foot.

Importance of Gas Storage

Table 2 indicates that a uniform and dependable supply of gas is available at our plant at all times. The average daily gas production for January to October was 71,000 cubic feet. However, since individual days have shown productions as low as 60,000 cubic feet, it has been assumed for the purpose of this study that at all times 60,000 cubic feet of gas will be available as the dependable minimum per 24 hours for power generation purposes. The assumption is doubly conservative due to the fact that we have a reserve gas supply of approximately 45,000 cubic feet in storage under 6 inches water pressure. This reserve supply is held in our secondary digestion tanks, the upper portion of which are in reality single-lift gas holders. It becomes apparent that one of the prime requisites of a practical and successful sewage-gas engine installation is a gas holder having ample storage capacity to carry over during periods of lower-than-average gas production.

Hydrogen Sulphide and Its Removal

The presence of hydrogen sulphide (H_2S) in objectionable quantities in digester gas may prove injurious to the pistons and cylinder walls of gas engines. While hydrogen sulphide itself is not seriously corrosive, its products of combustion, water and sulphur dioxide (SO_2) unite to form the highly corrosive sulphurous acid (H_2SO_3). The same products of combustion result from the presence in the gas of any form of sulphur; therefore, any volatile sulphide is just as objectionable in an engine fuel as is hydrogen sulphide.

Where the sulphide content of a sewage gas exceeds 0.0/ percent by volume, or approximately 50 grains per 100 cubic feet, scrubbers should be used to clean the gas before it enters the engine. Sulphur as hydrogen sulphide may be removed by passing the gas through a bed of finely divided iron oxide and wood shavings. The iron oxide reacts with the hydrogen sulphide to form sulphide of iron and water, according to the following equation.

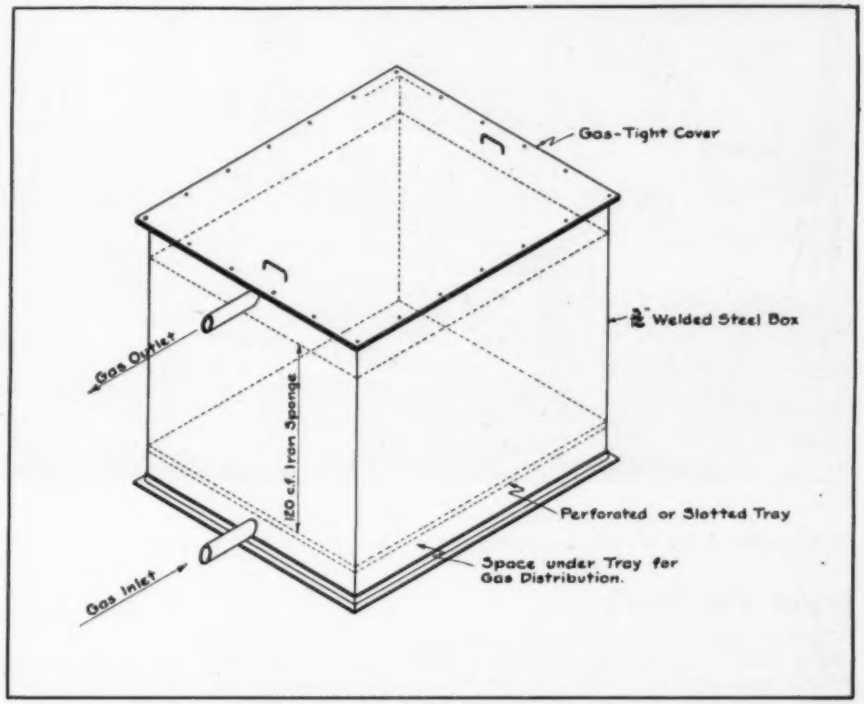
$$Fe_2O_3 + 3H_2S \simeq Fe_2S_3 + 3H_2O$$

The wood shavings merely serve to keep the mass of iron oxide open, forming an "iron sponge," so that the gas can pass through without too much resistance.

At most sewage treatment plants, little or no trouble has been experienced due to hydrogen sulphide in the gas. Some plants, however, have found it necessary to first remove the sulphur. Several of these have installed a commercial type of scrubber, among them the plants at Peoria, Illinois, Fort Atkinson, Wisconsin, and Battle Creek, Michigan.

An inexpensive, home-made gas scrubber can be constructed by following the design used at Galesburg, Illinois (3), as here sketched. It consists of a rectangular box providing a convenient depth of "iron-sponge" and a perforated or slotted tray which carries the sponge. The tray is supported about three inches above the bottom of the box to permit the gas to be distributed over the entire area before passing upward through the sponge.

Since the chemical action between hydrogen sulphide and the iron oxide takes place more readily at temperatures above 60° F., the box should either be located in a warm place, or insulated,



Home-Built Sulphide Scrubber at Galesburg, Ill.

or provided with heating coils. (The Peoria scrubbers here pictured are provided with artificial heat.) The inside of the box should be well coated with an asphaltic paint to prevent corrosion.

The calculations for a gas scrubber for 80,000 c.f.d. of gas containing 100 grains H_2S per 100 cubic feet are as follows:

1. Sufficient "iron sponge" should be provided to last about 60 days.
2. 1 cu. ft. of sponge contains about 20 lbs. of ferric iron.
3. 20 lbs. of ferric iron will theoretically react with 127,000 grains of H_2S.
4. Practical considerations cut this figure to about one-third, or 40,000 grains of H_2S.
5. Average H_2S content in the gas under question is 100 grains per 100 cu. ft.
6. Total H_2S in 60 days = 100 x 800 x 60 = 4,800,000 grains.

7. Total quantity of "iron sponge" required is

$$\frac{4{,}800{,}000}{40{,}000} = 120 \text{ cu. ft.}$$

The useful life of the sponge may be extended by regeneration. If the exhausted (sulphided) sponge is *carefully* exposed to the air, the iron sulphide will absorb oxygen, enabling the iron to revert back to its original ferric oxide condition as follows:—

$$2Fe_2S_3 + 3O_2 = 2Fe_2O_3 + 6S$$

This reaction generates so much heat that the sponge may take fire and be ruined. However, rate of regeneration may be controlled by wetting the old sponge thoroughly with water, and then removing it from the box to a pile in the open air. When it has changed from a black to a dark brown color, it is again ready for use. "Iron Sponge," thus regenerated, may be used two to three times before finally discarding.

When charging the box with sponge, care must be taken to pack uniformly. It should be lightly tamped several times while filling. Careful tamping around the sides of the box will prevent leakage of gas.

An accompanying picture shows three home-built scrubbers at Chicago Heights, Ill.

Three Home-Built Gas Scrubbers at Chicago Heights, Ill.
Beyond is 125 H.P. Climax engine direct connected to 2500-cu. ft. Pottstown blower.

Engine Gas Supply

Most engine manufacturers will guarantee the fuel consumption at full load to be not in excess of 10,000 Btu. per BHPH. This is equivalent to 15 000 Btu. per KWH. For a sewage gas having a low heat value of 575 Btu. per cubic foot, the consumption will be

$$\frac{15{,}000}{575} = 26.1 \text{ cu. ft./KWH}$$

At other loadings, the fuel requirements will be approximately as follows:—

1/2 Load—32.7 cu. ft./KWH
2/3 Load—29.3 cu. ft./KWH
5/6 Load—27.5 cu. ft./KWH

The total daily engine gas consumption shown in Table 3 was computed on the basis of using one engine up to 60 KW demand, and above 60 KW demand using both engines in parallel, each taking one-half the total load.

The sewage gas is introduced into the engine through a gas mixing-valve which mixes the gas with atmospheric air in the proper proportions. The function of this valve is similar to that of a carburetor on a gasoline engine. It should contain an air valve and a gas valve, each separately regulated in order that the fuel mixture may be changed to suit the varying Btu. content of the sewage gas.

The gas pressure ahead of the mixing valve should be reduced by means of a suitable pressure regulator to atmospheric pressure. To insure a constant supply of gas at atmospheric pressure at all times, a gas reservoir is usually installed between the mixing valve and the pressure regulator. The size of this reservoir depends upon the engine rating, but should not be less than about 30 cubic inches per horsepower.

Heat Recovery

(a) From Jacket Water

In most cases where sewage gas is being used for power, part or all of the waste heat from the engine is recovered for the heating of digestion tanks and buildings. If this were not done, the heat normally derived from the gas would have to be replaced by other fuels, such as coal or oil. Such an arrangement would probably prove economically unsound. Therefore, if gas is used for power purposes, no additional heating cost should be incurred, and such heat as may be required should be obtained from the engine waste heat, and from the excess gas.

The heat consumed in a gas engine, the heat wasted, and the heat which is recoverable depend upon the type of engine. For a 90 HP., four-cycle, slow-speed engine operating under full load, a typical heat balance is as follows:—

Heat going to useful work	25.5%
Heat to radiation	3.5%
Heat to jacket cooling water	35.5%
Heat to exhaust and friction	37.5%

Of the above heat, all of that carried away by the jacket cooling water can be recovered by connecting the jacket water piping into the hot water heating system. For best operating conditions, the cooling water should enter the engine at between 110° F. to 130° F., and should leave the engine at between 140° F. to 160° F. Approximately 3300 Btu./-BHPH must be removed from the engine jacket water to insure efficient cooling. Therefore, if the engine jacket water is passed through the digestion tank heating coils, these coils, acting as a water cooler, must be able to extract this amount of heat from the jacket water both winter and summer. If not, all or part of the jacket water must be circulated through a separate water cooler.

For a 90 HP engine operating at full load the heat recoverable from the jacket water is therefore

$$3300 \times 90 = 297{,}000 \text{ Btu/hr.}$$

The amount of a jacket cooling water required for a 30° F. temperature rise will be

$$Q = \frac{3300 \times 90}{30 \text{ (° Temp. diff.)} \times 8.34} = 1190 \text{ gph.}$$

In the jacket water system, therefore, we must provide a cooler (digestion tank or other) to extract the necessary heat from the water. We have calculated that a circulating water pump of at least 20 gpm (1190 gph) capacity will be required to ensure positive water circulation. A vented surge tank should be installed at the high point of the jacket water system, either between the engine outlet and the cooler, or just ahead of the circulating pump. Thermometers should be provided at the cold water inlet and the hot water outlet.

(b) From Exhaust Gas

A portion of the heat normally carried away by the exhaust gases is recoverable. The quantity recovered is governed by practical limitations in the size of the waste heat boiler, and also by the lower temperature limit to which gases can be safely cooled without condensation and the consequent corrosion of the surfaces with which they come in contact.

The importance of avoiding condensation of the moisture contained in the exhaust gases cannot be too highly stressed. The point of condensation, often called the dew point, has been found to be about 130° F. However, an exhaust gas temperature slightly higher than 130° F. is not sufficient to avoid condensation, due to the fact that exhaust gas temperatures drop very sharply when

they come in contact with surfaces having a water temperature below 130° F.

This sudden temperature drop is due to the inability of the gas film adjacent to the heating surface to transmit the heat from the main body of the gases to the water quickly enough. The resistance offered by the gas film causes the moisture in the gases to condense on the cold surfaces even though the main body of gases are at temperatures far above the dew point. Hence it is obvious that the water inlet temperature should not be less than 130° F., and the lower temperature limit of the main body of the exhaust gas should be well above the dew point. Experience has indicated that 300° F. is a safe minimum exhaust gas temperature.

Where 130° F. water is not available, the ideal method of reclaiming waste heat is by means of a waste heat boiler generating low pressure steam. The steam generated therein is delivered to an independent tubular heater through which water passes in the tubes. When the steam condenses in the independent heater, the condensate returns by gravity to the waste heat boiler where it is again evaporated. In this manner the cycle is closed and the water temperature remains well above 130° F., except for short periods when starting up after long shut downs. Nevertheless, practically all condensation with its consequent corrosion is eliminated.

At Rahway we have decided upon a waste heat boiler which will extract sufficient heat to cool the gas from 900° F. to 300° F. at full load. Obviously, at fractional loads, the final gas temperature will be under 300° F. due to the lower initial temperature and smaller gas quantities, but at low loads it will still be above the dew point. As a further precaution against corrosion, the cooling water will first be circulated through the engine jackets as the cooling medium for the engines. In so doing, the water will be preheated from 110° F. to 140° F. before entering the waste heat boiler. This double precaution against the possibility of a highly corrosive condensate appears to be the best guarantee for the long life of the equipment, and for low maintenance costs.

A waste heat boiler (see first cut) is a shel land tube type of boiler, the exhaust gases being passed through the boiler tubes, and the heat being absorbed by the cooling water which completely fills the shell and surrounds the tubes. The exhaust gases, cooled down considerably by the boiler, pass on out to atmosphere. The waste heat boiler itself will also serve as a silencer, no further silencing being necessary. Where a by-pass around the boiler is provided, a suitable silencer should be installed on the by-pass line. The arrangement proposed at Rahway will make it possible to by-pass all or a part of the exhaust gases around the boiler by means of a 3-way regulating valve. The piping is also so arranged that the jacket water can be by-passed around the waste heat boiler.

A pyrometer will be provided with a sufficient number of themocouple selection points to permit temperature readings of the exhaust gas to be taken at each cylinder, and at the discharge from the waste heat boiler.

Naturally, the amount of heat going into the exhaust gas depends upon the bore and stroke, number of cylinders, speed and type of engine. A four-cycle engine with water-cooled exhaust manifold will produce exhaust gases having temperatures of from 800° F. to 900° F., while the exhaust gases from a two-cycle engine will probably range from 300° F. to 500° F.

A typical range of exhaust gas quantities and the corresponding temperatures for a 90 H.P., four-cycle engine operating under several loadings is shown below. This data must be obtained from the manufacturer of the engine to be used.

	Exhaust Gas Quantity	Temperature
1/2 Load	683 Lbs./hr.	850
2/3 Load	845 Lbs./hr.	866
3/4 Load	918 Lbs./hr.	875
5/6 Load	994 Lbs./hr.	883
Full Load	1130 Lbs./hr.	900

Obviously, the quantity of heat which may be extracted from the exhaust gas depends upon the difference between the initial and final temperatures, and the specific heat of the gas. The specific heat of the exhaust gas from a gas engine will be about 0.24, this representing the ratio of the heat required to raise one pound of the gas 1° F., to the heat required to raise one pound of water 1° F. Therefore, the heat recoverable from the exhaust gas of a 90 HP., four-cycle engine operating under full load will be

$$1130 \text{ lbs./hr.} \times (900° - 300°) \times 0.24 = 162.720 \text{ btu/hr.}$$

(c) From Engine Radiation

The heat radiated from the engines (about 3.5%) cannot be transferred to the hot water heating system, but it does assist in the heating problem by partially heating the engine-room, thus relieving the heating system of this portion of the total heating load. Generally speaking, the radiation losses at the engine will be from 2 percent to 4 percent of the total heat input.

Heat from Excess Gas

At Rahway we have at present a hot water heating plant which heats the digestion tanks and all buildings. The boilers are operated exclusively on sewage gas. The Heat Exchange Diagram on the next page shows how the heated water from the engine-room will be run directly into the return line at the bottom of the boilers, and circulated through the boilers where the temperature will be raised to the desired degree. The return water to the engines will be taken from the digestion tank return water, which averages about 110° F. In using the boilers to "jack-up" the temperature of the heating water, we must rely on the sewage gas which may be left over after all engine requirements have been satisfied. Since the boiler efficiency approximates 68 percent, the boiler heat output which is available when one engine is operating under a 60 KW demand will be

$$\frac{22{,}500 \times 650 \times 0.68}{24} = 415{,}000 \text{ btu/hr}$$

This is shown in Table 3.

Thus it is apparent that the system will be extremely simple and yet highly flexible. The combined heat from the exhaust gases and the jacket cooling water can be used to heat the digestion tanks in summer, and to aid in the heating of tanks and buildings in the winter. Exhaust gas heat can be recovered, or it can be by-passed as desired. Since our average power load is 40 KW, it can be seen that sufficient heat is available to meet all normal winter heating requirements.

Construction and Operating Costs

Estimate of Cost

Two 90 HP.—60KW—100 KVA heavy duty gas-engine generator sets complete with gauge boards, gas reservoirs, Maxim silencers, exhaust gas pyrometers, electric alarm and shutdown systems, water circulating pumps, starting air equipment, gasoline carburetors, and installation	$19,000.00
Two Waste Heat Boilers	660.00
Two 3-Way Regulating Valves	240.00
Generator panels, with ammeters, voltmeters, wattmeters, frequency meters, voltage regulators, field rheostats, Synchroscope	2,340.00
Distribution Panel, Electric Wiring and Lighting	1,600.00
Station Piping	1,000.00
Outside Piping	3,500.00
Building (29' x 39' x [illegible])	6,000.00
1½ Ton Crane and Hoist	450.00
Engine Foundation (3 Engines)	800.00
Gas Meter	400.00
Contingencies	1,200.00
Total Estimated Construction Cost	$37,190.00
Legal, Administrative, etc.	3,000.00
Total Estimated Cost	$40,190.00

Amortization and Operating Costs

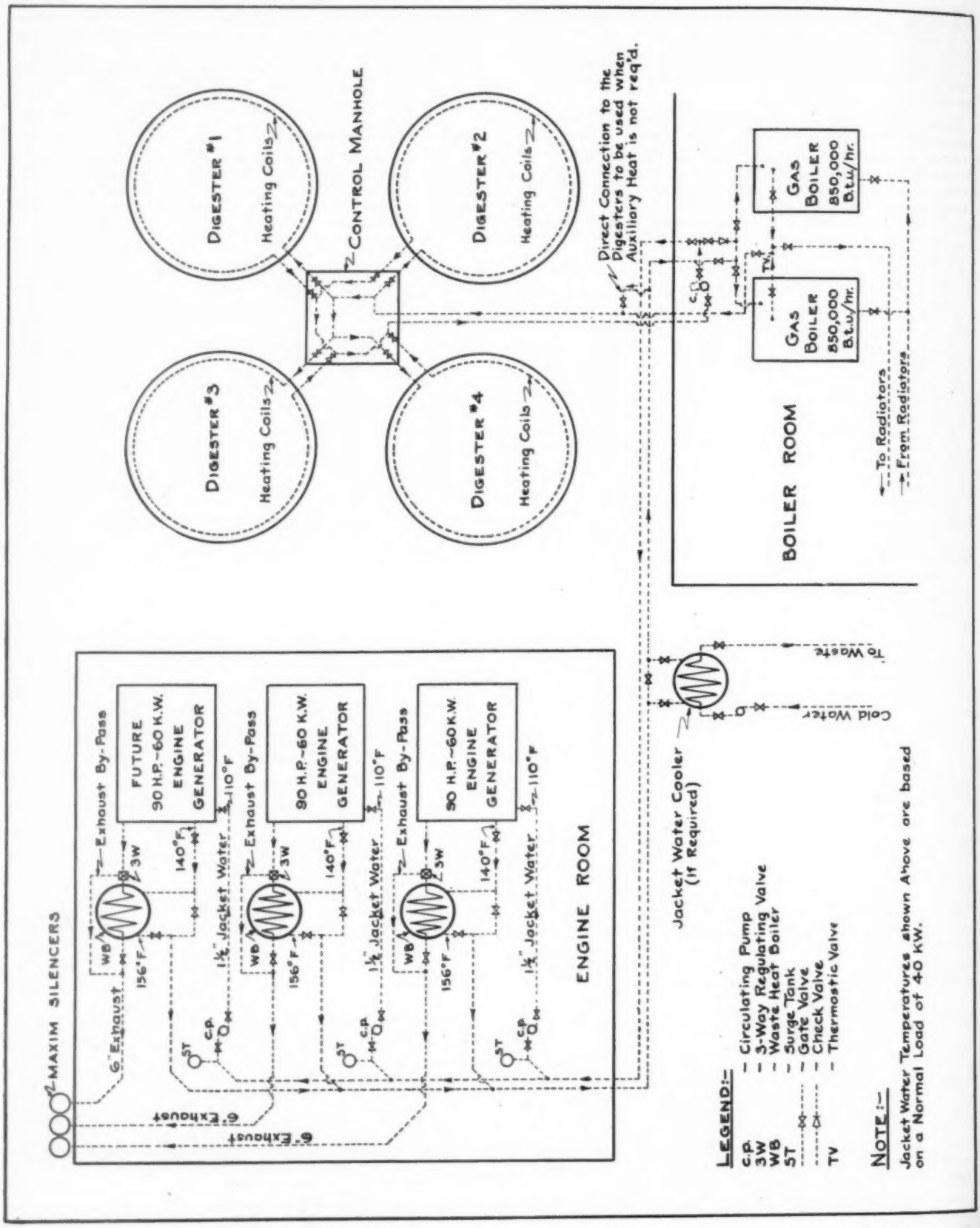
Gas engines, when on continuous service, are generally conceded to have a useful life of from 15 to 20 years. With two engines, each capable of carrying the normal load, the service is divided. Hence, the life of each engine may be conservatively set at 20 years.

By looking back at Table 1, it will be seen that in most cases the cost of additional labor to operate and maintain the engines is negligible. In fact, a number of the replies indicated that no additional labor cost was incurred.

Experience on the cost of repairs and lubricating oil seems to differ widely. A fair allowance for repairs is $2.00 per BHP per annum. This figure is somewhat higher than the engine manu-

facturers themselves predict on the basis of their own experience, and is thus felt to be sufficiently conservative for the purpose of this analysis.

Lubricating oil at most plants amounts to about 1 gallon for 2000 BHPH. However, oil consumption can be reduced somewhat by the use of oil refiners. At the Rahway plant, we estimate a total of 335,000 KWH per annum, which is equivalent to 500,000 BHPH. Our oil consumption, therefore, is expected to be approximately 250 gal.



Annual Charges and Savings

Interest on Investment @ 4%	$1,607.60
Amortization of Engine—$\frac{1}{20}$ x $21,300	1,065.00
Amortization of Miscellaneous Equipment—$\frac{1}{25}$ x $6,400	256.00
Amortization of Permanent Structures and Piping—$\frac{1}{30}$ x $12,490	416.33
Repairs—57 BHPH/annum @ $2.00	114.00
Lubricating Oil—250 gallons @ 12c	30.00
Estimated Annual Cost	$3,488.93
Present Annual Power Cost*	5,700.00
Net Annual Saving (based on present power cost)	$2,211.07

*Our purchased power cost will increase from year to year as the sewage load increases, hence the savings will likewise increase.

References

(1) W. B. Walraven "Development of Power from Sewage Sludge Gas," Sewage Works Journal, Vol. 4, Page 614 (July, 1932). "Experience with Gas Engine Operation—During Three and One-Half Years of Use," Water Works & Sewerage, p. 370, Vol. 83 (October, 1936). Water Works & Sewerage, p. 151, Vol. 80 (May, 1933).

(2) W. A. Sperry "Gas Engine Installation—Aurora, Illinois," Water Works & Sewerage, Page 11, Vol. 84 (January, 1937) and Page 327, Vol. 84 (September, 1937).

(3) L. W. Hunt, Chief Chemist, the Galesburg Sanitary District—by letter.

TABLE 1. TABULATION OF DATA ON POWER GENERATION FROM SEWAGE GAS

(Taken from replies to questionnaire)

Location	Pop. Served	Total H.P.	Make of Engine	Gas Production c.f.d.	Gas Consumption cu. ft.	Net Annual Savings	Annual Repairs	Annual Lubric. Oil	Additional Annual Labor Cost
Battle Creek, Mich.	36,300	60	Le Roi	59,000	8/BHPH	$2,004	$ 55	$ 90	None
Los Angeles, Cal.	374,000	450	Clark	250,000	24/BHPH	4,600	100	325	None
Green Bay, Wisc.	40,000	210	Worthington	40,000	26/KWH	2,835	96	189	$234
Cedar Rapids, Iowa	55,000	200	Worthington	147,760	15/BHPH	6,000	300	700	275
Janesville, Wisc.	20,000	30	Worthington	25,000	17/BHPH	850	600	110	150
Grand Rapids, Mich.	178,000	150	Buda	138,000	——	1,000	15	30	30
Fort Atkinson, Wisc.	6,000	15KVA	Le Roi	75,000	24/Kwh	1,950	300	75	None
Richmond, Ind.	28,000	120	Worthington	25,000	9.5/BHPH	6,000	None	200	None
Ann Arbor, Mich.	40,000	120	Worthington	50,000	15/BHPH	6,000	None	170	None
Topeka, Kans.	50,000	360	Worthington	Ample	——	5,400	200	425	——
Aurora, Ill.	49,000	140	Climax	49,500	21.8/BHPH	*	219	88	None
Kokomo, Ind.	36,000	45	Worthington	15,000	19/BHPH	1,800	None	55	None
Toledo, Ohio	60,000	535	Rathbun	250,000	9500Btu/BHPH	13,299	382	576	None

*Plant operating cost reduced 20%.

TABLE 2. GENERAL DATA ON POWER, GAS PFODUCTION, AND HEAT REQUIREMENTS

(As determined for the Rahway Valley Plant)

Month	Hourly Rates of Power Consumption			Max. Demand from Demand Chart KW	Gas Production		Heat Requirements				
							Digestion Tanks				
	Max. Day KWH	Min. Day KWH	Monthly Aver. KWH		Average c.f.d.	Maximum c.f.d.	Aver. Circ. Water g.p.h.	Temp. Diff. °F	Heat Req'd Btu/hr.	Heating of Buildings	Total Heat Required Btu/hr.
January	80	23	35	99	63,000	85,000	3,600	18	540,000	400,000	940,000
February	57	30	39	70	68,000	86,000	3,500	17	485,000	400,000	885,000
March	73	33	42	78	67,000	86,000	3,620	21	635,000	350,000	985,000
April	60	30	39	76	72,000	89,000	3,500	23	670,000	200,000	870,000
May	37	27	31	50	61,000	79,000	3,250	19	516,000	75,000	591,000
June	60	23	32	51	73,000	87,000	2,780	23	535,000	0	535,000
July	113*	27	43	119*	72,000	85,000	3,480	13	377,000	0	377,000
August	40	27	35	72	70,000	81,000	3,400	16	453,000	0	453,000
September	114*	27	39	124*	85,000	104,000	3,100	15	387,000	0	387,000
October	40	27	37	60	78,000	103,000	3,250	17	462,000	80,000	542,000
Average					71,000						

*Exceptionally Heavy Storms.

TABLE 3. FUEL AND HEAT BALANCE

Daily Load	Engine Gas Consumption		Excess Gas*	Boiler Heat Available from Excess Gas**	Recoverable Heat		Radiation from Engines		Total Heat Available	Aver. Heat Req'd during Winter Months	Max. Heat Req'd for a Zero Day
KWH	Btu/KWH	c.f.d.	c.f.d.	Btu/hr.	From Jacket Water Btu/hr.	From Engine Exhaust Btu/hr.	% Loss	Heat Btu/hr.	Btu/hr.	Btu/hr.	Btu/hr.
80	16,800	56,000	4,000	74,000	396,000	238,000	2¼	30,000	738,000	850,000	1,070,000
70	17,600	51,200	8,800	162,000	345,000	216,000	2½	34,000	757,000	850,000	1,070,000
60	15,000	37,500	22,500	415,000	297,000	163,000	1½	15,000	890,000	850,000	1,070 000
50	15,800	33,000	27,000	495,000	248,000	138,000	2	17,000	898,000	850,000	1,070,000
40	16,800	28,000	32,000	590,000	197,000	119,000	2¼	16,000	922,000	850,000	1,070,000
30	18,800	24,000	36,000	660,000	149,000	95,000	2½	16,000	920,000	850,000	1,070,000

*Daily Average Gas Production to be expected is 60,000 c.f.d.
**Hot Water Boiler Efficiency estimated at 68%.

NOTES:
High heat value of sewage-gas = 650 Btu; low heat value = 575 Btu.

Fuel requirements and heat recovery, based on the following:
Engine—Worthington 90 H.P.—60 K.W. Type BG-3.
Waste Heat Boiler—Davis Paracoil N-70.

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Ferri-Cl_3or coagulates sewage and industrial wastes, thus causing more rapid precipitation in sedimentation plants and faster filtering through vacuum filtration systems. It is most effective in the pretreatment of industrial wastes which offer change in characteristics almost hourly.

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FOR COAGULATING SEWAGE

Ferri-Cl_3or provides an inexpensive and efficient method of dealing with plant overloads, and reduces original plant investment by increasing the capacity of the sedimentation plant.

AMOUNT OF FERRI-CL_3OR TO BE USED

The accepted procedure in determining the dose of Ferri-Cl_3or required to coagulate a given sewage is to set up "jar tests" with sewage to be tested. 2 qt. Mason Jars and stock solutions of Ferri-Cl_3or and lime, consisting of 10 grams per liter of distilled water, are used. Place one liter of sewage to be tested in each of several Mason Jars. Add to the sewage in each jar, successively larger doses of Ferri-Cl_3or stock solution. Stir all samples thoroughly for several minutes and let stand for 1 hour. Observation of the several samples will determine the best dosage. If lime is required to provide sufficient alkalinity for satisfactory coagulation, follow the same procedure outline for Ferri-Cl_3or. The amount in lbs. of Ferri-Cl_3or or lime required equals the number of c.c. used in the selected test × 10 × total sewage flow (m.g.d.) × 8.33.

FOR SLUDGE CONDITIONING

Ferri-Cl_3or is accepted as the agent most efficient from the standpoint of performance and cost for the coagulation of sludge prior to its dewatering in the filter.

AMOUNT OF FERRI-CL_3OR TO BE USED

Using the Buchner Funnel Test, the time periods required for the vacuum to break with varying quantities of coagulant are recorded. 2 to 3 minutes is satisfactory and 1 to 1½ minutes is very good and should be used for plants where the sludge is held as in batch-mixing.

Various combinations of Ferri-Cl_3or and lime should be tested until the relative quantities for optimum operation are determined.

The approximate quantities of chemical to be used in the plant can be determined from the laboratory tests, provided, of course, that the same strength chemicals are used in the plant. The quantity of Ferri-Cl_3or solution in gallons per 1000 gallons of sludge will be 5 times the c.c. used per 200 c.c. of sludge in the test. Likewise, the quantity of lime in pounds per 1000 gallons of sludge will be 42 times the grams used per 200 c.c. of sludge.

PREPARATION OF FERRI-CL_3OR SOLUTION

The main difficulty in dissolving Ferri-Cl_3or arises from the fact that the saturated solution is heavier than water. This means that the liquid in a simple container may have a layer of pure water at the top, even with undissolved crystals at the bottom. To overcome this difficulty, three methods have been developed.

1. Automatic gravity circulation by placing the salt on a wooden grid elevated or suspended one-half way in the tank.

2. Mechanical mixing by (a) stirring, (b) by air agitation, and (c) liquid recirculation.

3. Melting: Ferri-Cl_3or melts at 98.6 to 102.2°F. and so can readily be liquefied by relatively small amounts of heat from exhaust or live steam, flue gases, oil, gas or electricity. The dissolved salts can be poured into the water.

Ferri-Cl_3or FERRIC CHLORIDE 60% ($FeCl_3$) **is ISCO's registered name for Ferric Chloride developed and manufactured especially for Sewage and Water Treatment Use.**

ISCO Ferri-Cl_3or is used in America's newest and most modern sewage treatment plants.

FERRIC SALTS IN WATER AND SEWAGE TREATMENT

By FRANCIS K. BURR
Technical Service Department
Monsanto Chemical Co., Boston, Mass.

ALTHOUGH ferrous sulfate, historically known in the trade as copperas, had been used in water purification in this country as early as 1898, there is no mention of the use of salts of ferric iron until 1910, when Bull,[1] who incidentally initiated the 1898 experiments at Quincy, Illinois, with iron salts as coagulants, did some experimental work with ferric chloride at Chicago and Toledo. He developed a process of making chlorine electrolytically and by passing the chlorine water through iron fillings produced ferric chloride. This he found to be an effective coagulant, but the method of producing a coagulant was too complicated to prove attractive when ready-to-use coagulants could be purchased for application with simple equipment.

There seems to be a great void between that date (1910) and the late "twenties" as far as ferric salts are concerned. The use of copperas (ferrous sulfate) and lime was noted at scattered points. Meanwhile Hutin,[2] in 1918, reported in "Revue Products Chimiques" a method for making ferric sulfate from pyrite cinder and suggested its use as a coagulant for water purification, for coagulation of blood, and for the prevention of nauseous odors in abattoirs. For the most part, however, the researchers during this period were more concerned with removing iron from water than with any thought of adding it as a coagulant.

Between 1923 and 1925 Miller[3] published the results of coagulation studies which included test work with iron salts. In 1926 the Chicago Sanitary District established the fact that ferric iron was the best coagulant in sewage sludge dewatering. Houston Tex., and Milwaukee were prompt to adopt the use of ferric coagulant for sludge dewatering. Shortly afterwards what was perhaps the first successful application of a ferric salt in water treatment occurred at Elizabeth City, N. C., in 1927, where Enslow[4] and Hedgepeth[5] devised equipment for making "chlorinated copperas" on a continuous basis with the use of a dry feed machine and chlorinator, and applied the mixed ferric salt to a soft, highly colored water. The technique of producing this ferric salt was a new one and it attracted wide interest because of its comparative simplicity and adaptability to water and sewage treatment processes.

This work was followed shortly by a similar experiment by Decker[6] at Chickasaw, Ala. (1930), using the same reagent on the same type of water, and later on the process was proven advantageous by Billings[7] for a hard turbid water at Dallas, in 1934. Meanwhile, in 1929, at Baltimore, Hopkins[8] used chlorinated copperas successfully for manganese removal in the pH range slightly above 9.0.

While these strides were being made in the field of water treatment, ferric chloride and chlorinated copperas were receiving attention in the sewage treatment field as coagulants and sludge conditioning agents. Mohlman and Palmer,[9] in 1928, reported results of a study of conditioning activated sludge in which ferric chloride was found to be the superior agent. Not long after this the Scott-Darcey process for the production of ferric chloride at water and sewage treatment plants was introduced. This process involved the reaction of chlorine and scrap iron in a reaction tower.

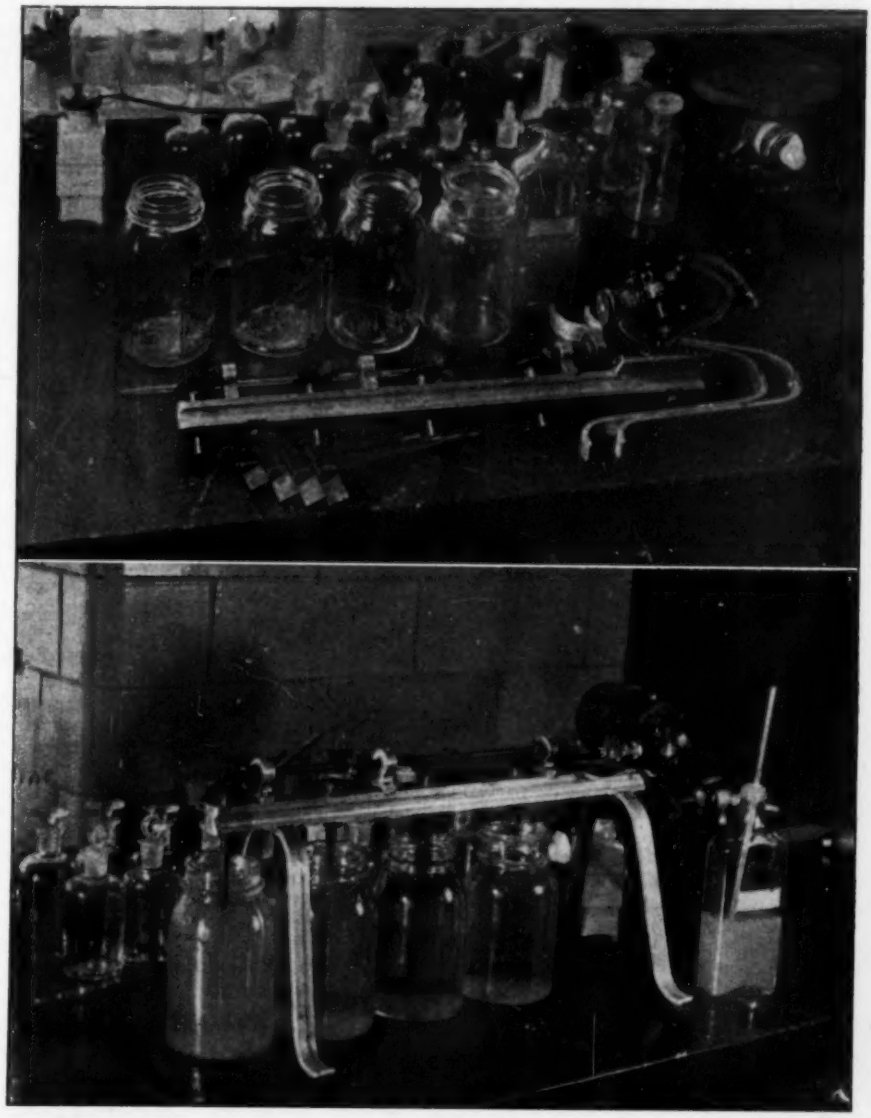
Craig, Bean and Sawyer[10] ran experiments in Providence during 1932, with chlorinated copperas. They were studying manganese removal at a pH slightly above 9. Their studies resulted in savings of 25 per cent over previous results with unchlorinated copperas. The greater efficiency of the ferric ion accounted for this. In 1933, Holton and Bean[11] reported tests with ferric sulfate which proved more economical than the chlorinated copperas.

A Factory Made Ferric Sulphate Appears on the Market

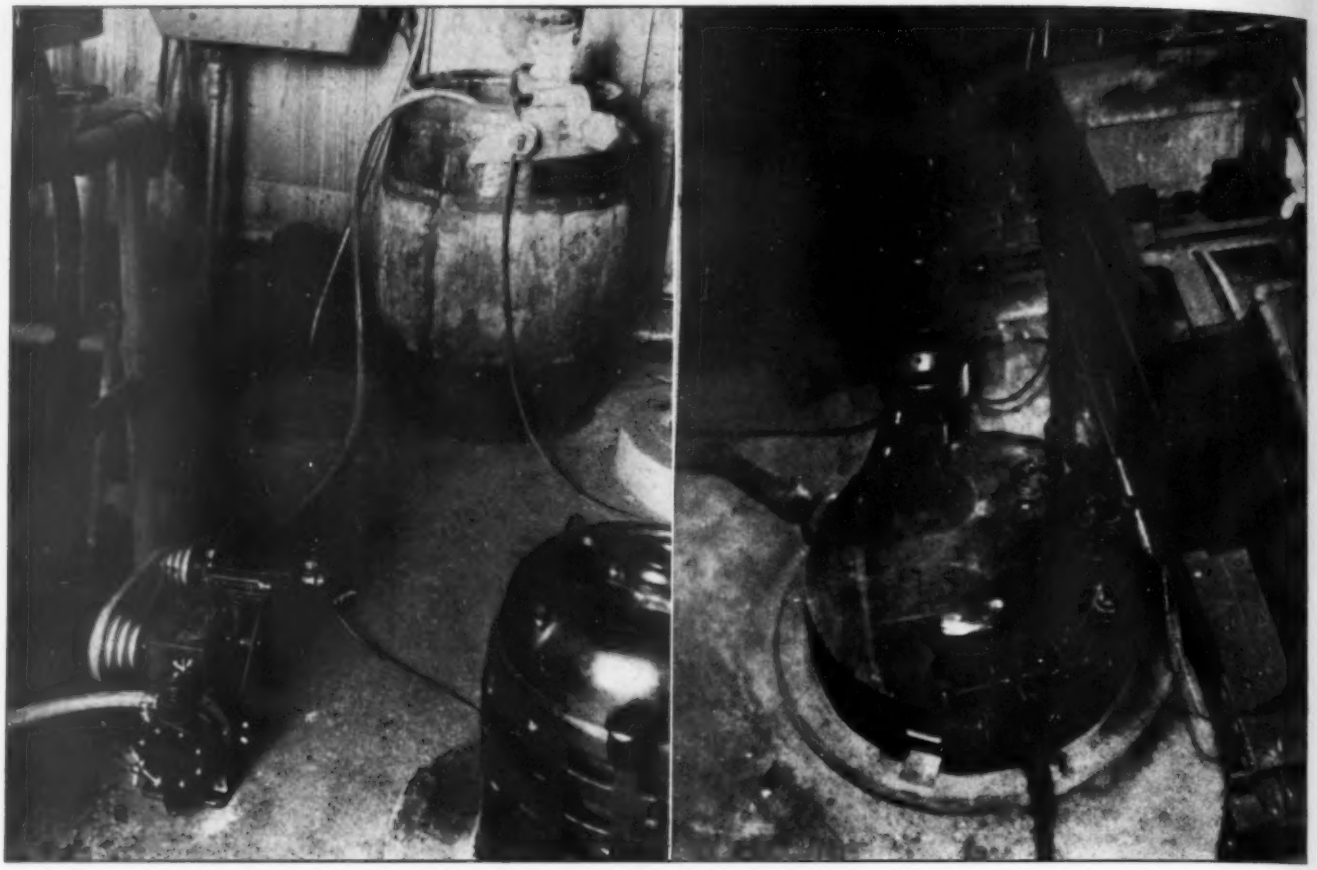
This was the starting point for "Ferrisul," as it was the material used in these tests and was then only being produced on a pilot plant scale. Monsanto chemists during this period of renewed interest in ferric salts had developed a process for producing anhydrous ferric sulfate from pyrite cinder (which is essentially ferric oxide) and sulfuric acid. This was the first instance of the production of this material in a dry free-flowing condition on a commercial basis. It possessed distinct advantages in handling, shipping and storage over other ferric salts while possessing a high ferric iron content.

As indicated by Black[12] and substantiated during recent years in field work, the characteristics of ferric salts which make them valuable in water and sewage coagulation are:

1. They contain the trivalent ferric ion.
2. They react rapidly to form a heavy, spongy, absorptive, hydrous ferric oxide floc with quick settling properties.



Portable Jar Test Outfit of the Author. Knocked Down and Set Up for Determining Optimum Coagulant Dosages.



Ferrisul Feeding

On left is a typical solution feed arrangement for small plants, involving feed control with a midget "Chlorofeeder." On right is a dry-feed arrangement, in which a "Waytrol" feeder delivers Ferrisul to the flash dissolving pot with motordriven agitator.

3. They are capable of coagulation over a wide pH range—namely, from 3.5 up, which covers the entire useful range as far as practical water and sewage treatment is concerned.

Where Ferric Coagulation Exhibits Distinctive Advantages

With these facts presented, we are frequently asked: "What is the optimum pH for coagulation with Ferrisul?" No concrete answer can be given that will cover all cases, since the optimum pH varies with the peculiarities of the water under consideration and sometimes it is necessary to treat in a range other than the optimum to remove certain undesirable materials. One such instance will be discussed later in this paper.

It will be granted that in the majority of cases water can be economically coagulated with aluminum sulfate, since in most cases water is coagulated at or near the neutral point. It has been proposed, however, by Pirnie[2] that where possible it is better to coagulate in the alkaline range slightly above the stability point, accomplishing in one operation the removal of dissolved iron and manganese when present and reducing the corrosiveness of the water. This method has been used in many instances and it eliminates the addition of alkali to the clear-well which sometimes causes after-precipitation.

This method is not applicable to waters of high color unless coagulation is a two-stage affair in which the water is first coagulated in the low pH range. After the bulk of the floc has settled the pH is raised to the desired point prior to filtration as was done in the Elizabeth City pioneering application. When properly applied this procedure is very effective, accomplishing color removal without the usual application of an acid water to the filters. It also acts to insure an absence of residual iron should the operator apply an overdose which depresses the pH to a point in the neighborhood of 3.0 or lower. It can be seen from the above example, and the process suggested just before it, that a wide range coagulant such as ferric salt is indicated.

To summarize briefly the more or less specific applications, including those mentioned, we find Ferrisul is used:

1. To clarify lime-softened waters.
2. To remove color in the low pH range.
3. To remove manganese in the alkaline range.
4. To clarify unsoftened waters which are turbid and contain high permanent hardness.
5. To promote rapid floc formation under cold water conditions.

Discussion

Clarification of lime-softened water is an ideal field for ferric salts. Efficiency is very high and coagulant residuals are practically nil in this relatively high pH range.

The removal of color from soft waters with Ferrisul frequently occurs in a pH range where alum is far less effective. In treatment the pH may go as low as 3.5 and very rarely is it necessary to use corrective alkali in coagulation to stay within the optimum range. This is because in alum coagulation it is frequently necessary to add lime or soda ash, since the amount of aluminum sulfate needed to coagulate the color produces a drop in pH below the point at which the aluminum salt will floc.

In Manganese Removal

The removal of manganese is usually accomplished at about pH 9.0 when using Ferrisul. This subject has been fairly well covered in the literature and for the present the author wishes to discuss only a few interesting points that have come to light in the past year or so.

During the fall of 1941, Ferrisul was applied for manganese removal and under the prescribed conditions in the water treatment plant at Winston-Salem, N. C. Removal of manganese and iron was complete, to all intents and purposes, being less than 0.05 part per million consistently. However, the water in the clear-well showed 0.5 part per million turbidity throughout the run despite efforts to reduce it. When the manganese was no longer a factor in the raw water, coagulation was carried out in the vicinity of pH 7.0 and the water in the clear-well again approached zero turbidity. Apparently there was a colloid present in the raw water that could not be coagulated in the higher pH range. This one-half part per million turbidity was not at all serious but it was puzzling. This illustrates a condition where a ferric salt was used in a range other than the optimum, only because manganese removal was the most important consideration. During the summer of 1942 at Durham, N. C., manganese occurred in a water which contained a moderate amount of color, which is unusual in itself. During the summer and fall of 1941

this did not occur. The color was present to the amount of 20 or 30 p.p.m. for a few days and then dropped to about 15 p.p.m. In our experience a color of 10 parts or more has been rare in a manganese-bearing water. The treatment on the alkaline side did not remove the color effectively.

R. S. Phillips,[14] at Durham, in reporting his experiences in WATER WORKS AND SEWERAGE for July, 1943, stated that tests were made with bleaching clays, sodium aluminate and carbon without success. The addition of 8 p.p.m. of chlorine was successful in reducing the color, but since chlorine is needed in the war effort, this solution had to be foregone. The color can be removed in the low pH range with Ferrisul or alum but this does not remove the manganese which is the more objectionable impurity. At present a two-stage treatment is not practical at Durham and, therefore, the high pH range was adhered to.

Under clarification of water containing a high permanent hardness, an interesting comparison which was made at Cincinnati by Bahlman[15] of Ferrisul and copperas should be reported. Coagulation was carried out in the range favorable to copperas, namely, about pH 8.8 to 9.0. One pound of Ferrisul was found to be equal to two pounds of copperas. The iron content of these materials is 25 and 20 per cent, respectively. Thus, we get an interesting example of the greater effectiveness of the ferric ion even though the raw water contained dissolved oxygen in quantity ample for oxidation of the ferrous ions added. Such comparative results would have been expected in waters or sewages void of dissolved oxygen or essentially so.

A Cold Weather Coagulant

During the cold months of the year difficulty is frequently encountered in the coagulation of water with alum. Pinpoint flocs result, lowering filtration efficiencies. Ferric salts are not so sensitive to temperature changes and that satisfactory flocs can be maintained with them in the critical near freezing range. The application is not widespread but in several instances has proven its worth.

Sewage Treatment

The factors which make Ferrisul valuable in water treatment apply to sewage coagulation as well. In addition there is the factor of odor reduction due to the control of sulfides. This application has been employed frequently with success as far as the odor condition is concerned. It should be reported, however, that in several instances the increase in sludge resulting from the iron addition overloaded the digester to the point where treatment had to be discontinued. Incidentally, gas production increased tremendously, indicating not only increased solids removed in clarification but also greater activity in the digestion process.

A recent paper of interest by Phelps and Bevan[16] discussed at considerable length the effect of ferric floc in the Guggenheim process for sewage treatment. It mentioned the beneficial effect of this floc on the growth and activities of those organisms normally encountered in biochemical treatment of sewage with aeration. This process is similar to the activated sludge process but requires a considerably shorter period of treatment. It is proving successful in use in several cities as well as in the treatment of industrial wastes.

Although the use of ferric chloride and chlorinated copperas has held the spotlight for many years in the field of sludge conditioning, there have been recent developments indicating that ferric sulfate can be economically used for this application. Previous unsuccessful results were believed to be due to the negative effect of the sulfate ion. Now it is known that by controlling the technique of chemical dosing and mixing that satisfactory results are obtainable and these facts have been substantiated in several instances. The economics of the situation are now based more nearly on the unit cost of ferric iron.

The use of ferric sulfate in the drying of digested sludge on sand beds has been tried successfully. The use of a coagulant here accelerates drying by increasing drainability and the presence of an iron salt reduces sulfide odors where odor control is needed.

The use of Ferrisul in waste treatment is quite similar to its application in sewage treatment. Because wide variations in pH are encountered, a wide-range coagulant is indicated. Ferrisul has been applied with effectiveness to the treatment of dairy, textile, packing-house, brewery, paper mill and other industrial wastes as well as combined domestic and industrial wastes.

Silica Removal in Boiler Feed Water Treatment

An industrial application of widespread interest is the removal of silica in the pre-treatment of boiler water. Schwartz[17] has covered this application very adequately in past treatises and more recently at the meeting of the American Water Works Association held in Chicago in June, 1942.

Our research has shown that silica exists in natural waters in two primary forms, namely, negative colloidal silica and soluble silica. The negative colloid is easily removed by coagulation with Ferrisul at a pH of 4.5 and can also be removed in the alkaline range at a pH of 9 if calcium is present. The soluble silica is much more difficult to remove since the ions must be adsorbed on the floc. This is best done at a pH of 9.0. If soluble silica is present in large quantities, a rather high dosage of Ferrisul is needed. Should this high dosage result in the addition of too high a content of dissolved solids to the boiler water, it is possible to circumvent this by preforming the floc, followed with washing by decantation. Then the preformed floc is mixed with the silica bearing water, adsorbing the silica without the addition of dissolved solids.

Greater efficiencies could be realized in silica removal if a true counter-current system of adsorption were employed. Perhaps a series of tanks could be used so that the raw water containing high silica would first contact an old mass of floc with some silica on it and then pass on to increasingly fresh floc, or it might be feasible to design an efficient counter-current system in an up-flow tank adding fresh floc at the top. This would greatly reduce the amount of Ferrisul needed, but at present no practical method of applying this procedure has been developed.

Incidentally, these silica studies have led to an explanation or confirmation of the work by Baylis[18] in the matter of silica alumina flocs. In our work with the synthetic waters, we were able to produce waters of varying ratios of negative colloidal silica and soluble silica. When acid first is added, the silica particles are small and carry heavy charges per unit of silica. At this point silica would not be recommended as an addition agent if low dosages of coagulant are desired, since it increases tremendously the charges to be neutralized.

Colloidal particles continue to grow in size and decrease in charge per unit of silica until finally a gel results. At that point the silica is no longer useful as a coagulant, but at an intermediate point an optimum condition is reached where a very low dosage of coagulant will produce coalescence of the silica particles, forming a bulky floc which is a combination of hydrous silica and hydrous alumina or ferric oxide.

Another interesting application in the field of boiler water treatment is the Walsh[19] patent concerning a process for softening water with a phosphate salt and Ferrisul. The water is treated with a definite amount of a phosphate salt according to its hardness, followed by the addition of 5 p.p.m. of ferric sulfate. Ordinarily the reaction of the phosphate with calcium and magnesium salt is very slow and impractical in external treatments. However, in this case the ferric sulfate catalyzes the reaction and it rapidly proceeds to its conclusion. A treated water of essentially zero hardness is the result.

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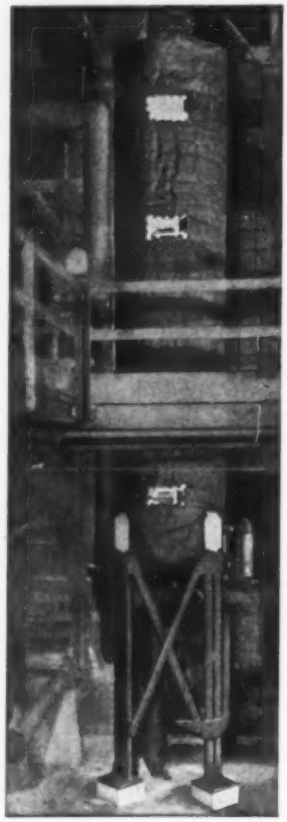
PENNSYLVANIA SALT MANUFACTURING COMPANY

1047 WIDENER BUILDING, PHILADELPHIA, PA.

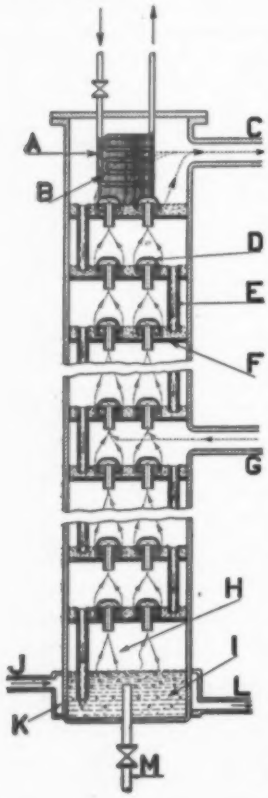
NEW YORK • CHICAGO • ST. LOUIS • PITTSBURGH • WYANDOTTE • TACOMA

• LIQUID CHLORINE

A clean amber-colored liquid about one and one-half times as heavy as water. Supplied in steel containers which are under pressure at temperatures above 30.1° F. It is only slightly soluble in water, its maximum solubility in distilled water being about 1% at 49.2° F. When pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is about two and one-half times as heavy as air. It is non-inflammable, non-explosive, and a non-conductor of electricity. Generally, in the absence of moisture it is not corrosive to common metals at temperatures below 212° F. Moist chlorine or aqueous solutions of chlorine require special equipment materials for handling.



Chlorine has been proved to be the most efficient, flexible and economical agent for sterilizing water supplies; and it is also used as a sludge stabilizer, a taste and odor eliminator, a precipitating aid, and, in sewage treatment, for disinfection, for B.O.D. reduction and odor control. The quantity of chlorine required in water purification and sewage treatment processes depends upon the quality of water, the point of application, and the object desired. Penn Salt Liquid Chlorine is particularly adapted for such processes because of its high purity and freedom from objectionable "taffy" or chlorine gum, achieved by means of the specially designed Penn Salt fractionating column which eliminates practically all harmful impurities from the chlorine.



Operating Diagram of the Chlorine Fractionating Column

A. Refrigerating Coil
B. Condensing purified chlorine
C. Purified chlorine outlet
D. Bubble cap
E. Downtake for reflux
F. Tray or plate
G. Raw chlorine inlet
H. Chloroform vapors
I. Chloroform and dissolved impurities
J. Steam inlet
K. Heating jacket
L. Condensed water
M. Drain for impurities

This Liquid Chlorine is supplied in seamless steel cylinders in sizes ranging from 10-lb. net to 150-lb. net. They comply with requirements of the Interstate Commerce Commission concerning specifications, retesting, loading, maintenance. Liquid Chlorine is also shipped in multiple-unit tank cars holding 15 containers of one ton each, and in single-unit tank cars of two sizes, 32,000 and 60,000-lb. respectively. The care with which all Pennsylvania Salt packages are cleaned and double-checked, coupled with the quality of Penn Salt Liquid Chlorine, assure maximum safety and convenience in chlorinator operation.

• PERCHLORON

Per*chlor*on is a high strength calcium hypochlorite, having a guaranteed active ingredient of not less than 70% calcium hypochlorite or available chlorine. It is free flowing, concentrated and retains its labeled strength for one year or more under normal storage conditions. It weighs approximately 52.5 pounds per cubic foot. It is composed of finely divided particles, all of which will pass a 20 mesh screen and be retained on a 65 mesh screen. It is quickly soluble in water, and is useful as a second line of defense for water purification in cases of emergency, when supplies of liquid chlorine may be temporarily cut off. Per*chlor*on is also used for sterilizing new mains, as well as clear wells and filters; valuable for sewage treatment, too. Many leading swimming pools sanitize their water with Per*chlor*on, use it to combat slime and algae growths, and to control athlete's foot by means of trays and spraying locker and washrooms. Per*chlor*on is supplied in handy-sized cans equipped with Kork-N-Seal covers, 9—5-lb. cans to the case. Also in 100-lb. drums.

● AMMONIA, Anhydrous

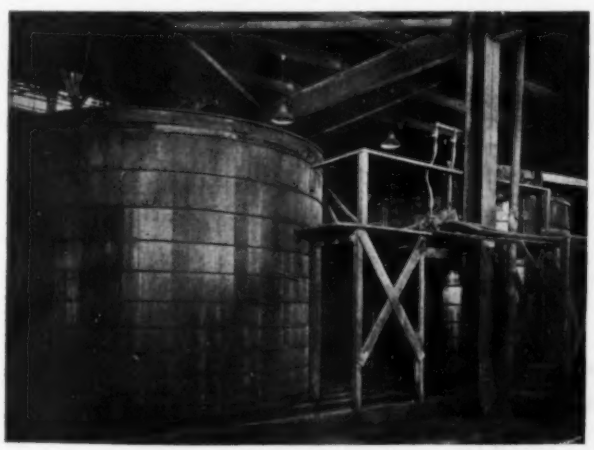
A colorless liquid which at 70° F. is 0.61 times as heavy as water, and weighs 38.0 lb. per cubic foot. When pressure is released, it volatilizes to a colorless gas of penetrating odor, which is 0.597 times as heavy as air at standard conditions. Dry ammonia is not corrosive to the common metals, but moist ammonia attacks copper and all its alloys, hence iron pipe and fittings are always recommended. Ammonia is exceedingly soluble in water. At 32° F., 1150 volumes of ammonia will dissolve in 1 volume of water, or 47.3% by weight.

This characteristic of ammonia is utilized in the dry feed ammoniators in water works. It is also useful in the chloramine process, in which ammonia is applied along with chlorine to prevent the formation of chlorinous, phenolic or medicinal tastes; and for stabilizing or prolonging the sterilizing action of chlorine. Ratios of ammonia to chlorine varying from 1:1 to 1:12 have been effective, with points of application ranging over the entire purification process. To prevent taste intensification, the ammonia must be applied before the chlorine.

Pennsylvania Salt Anhydrous Ammonia is supplied in special improved cylinders of seamless drawn steel which are light, strong and easy to handle and store. Gas may be withdrawn either with a cylinder standing upright on a scale for weighing, or with the cylinder lying horizontal, whichever is most convenient.

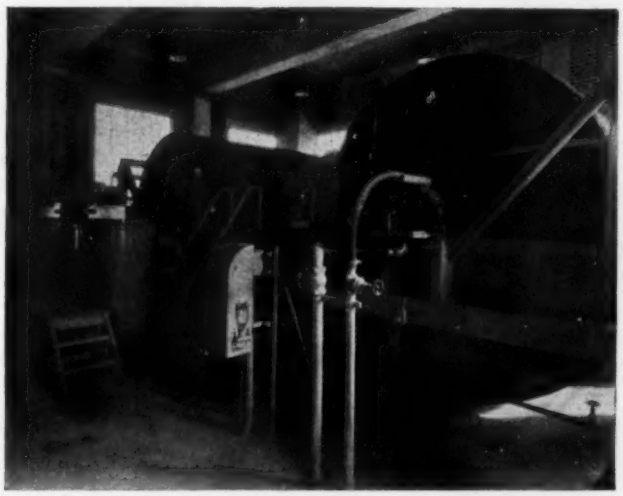
● FILTER ALUM (Sulphate of Alumina)

This product is the principal coagulant used in water purification; and Penn Salt Filter Alum has been adopted by many water works superintendents and engineers. Available in any quantity from a single bag or barrel to carload lots. Bags and barrels are paper lined as a protection against atmospheric moisture.



● FERRIC CHLORIDE

In liquid form it is an aqueous solution, the concentration of which is governed by the outside temperature and varies from 39% $FeCl_3$ in extremely cold weather to 45% in extremely hot weather. Pennsylvania Salt also supplies ferric chloride in an anhydrous form which is water-free and as near to 100% $FeCl_3$ as is permitted by impurities in the steel scrap from which it is made. Ferric chloride is a positive coagulant, producing clean-cut flocculation in economical doses. In most communities, depending upon shipping costs, ferric chloride offers vast savings over alum. The aqueous solution is shipped in rubber-lined tank cars holding 8,000 gallons and averaging 40,000 lb. of dissolved $FeCl_3$ per car. Anhydrous ferric chloride is shipped in non-returnable steel drums, 150 and 400 lb. sizes.



● SODIUM ALUMINATE

An alkaline compound of alumina and caustic soda, used both for softening water and as a combined coagulant and softener. Most effective in water requiring an alkali with the alum. Shipped in thin steel non-returnable drums, net weight 100 and 400 lb. each; and in 100-lb. moisture-proof burlap bags.

● SODA ASH
CHLORIDE OF LIME, and
CAUSTIC SODA

are among the other chemicals made by Pennsylvania Salt and used in water purification and sewage treatment. Ask us for detailed information and expert technical assistance.

DOW

FERRIC CHLORIDE

60% CRYSTALS — 37-47% SOLUTION

FOR SLUDGE CONDITIONING

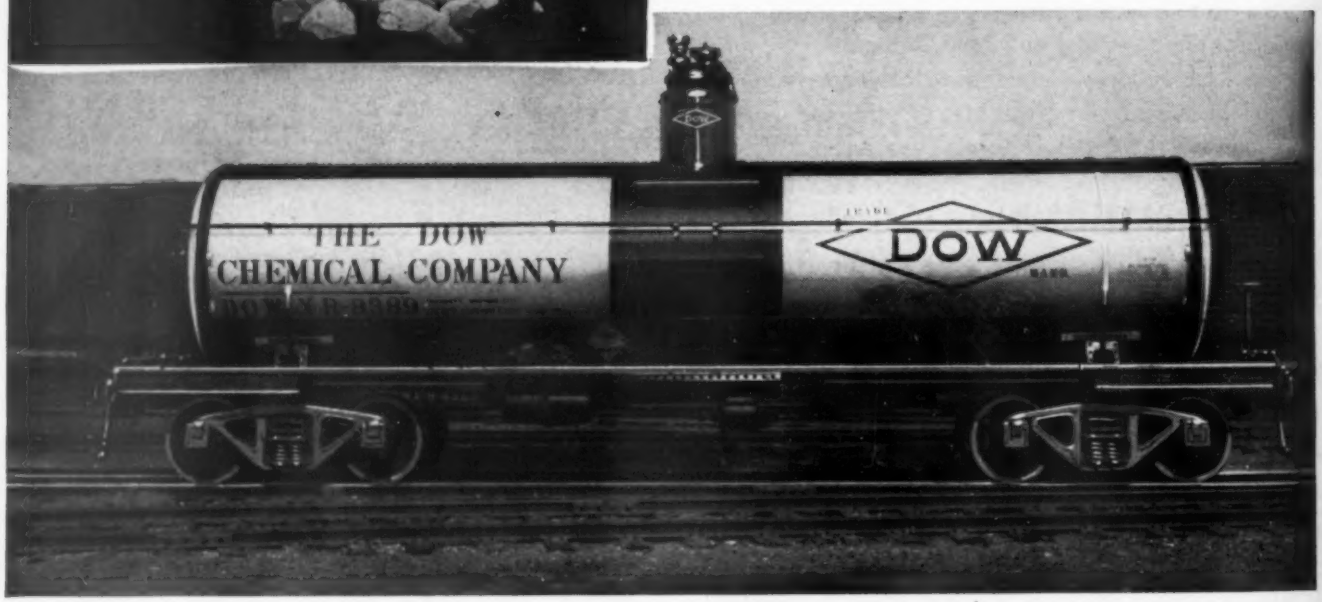
- Minimum chemical and operating costs.
- Cuts dewatering equipment cost — increases performance.
- Gives higher filtration rate.

FOR SEWAGE COAGULATION

- Greater removal of suspended solids.
- Lower 5-day B.O.D.
- Increased flexibility to meet peak loads and low stream flows.
- Economical effluent improvement.
- Reduction of hydrogen sulphide odors.

FOR WATER TREATMENT

- Forms a compact, quick settling floc with complete precipitation at any pH value above 5. Retains effectiveness in cold weather.
- Effectively removes large quantities of coloring matter. Precipitates tannin compounds at pH of 5 or below.
- In conjunction with lime, removes iron and manganese.
- Reduces taste and odor by removing H_2S.



Dow Ferric Chloride 37-47% Solution is shipped in tank cars. Ferric Chloride 60% Crystals are packed in 300 lb. and 500 lb. heavy wooden barrels, permitting storage without deliquescence of the crystals.

Dow Technical Service covering design and operating problems of sewage disposal plants is available upon request to engineers.

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FERRIC CHLORIDE

Practical Aspects of Storing and Handling

By L. L. HEDGEPETH and J. M. POTTER
Technical Service Dept., Pennsylvania Salt Mfg. Co., Philadelphia, Pa.

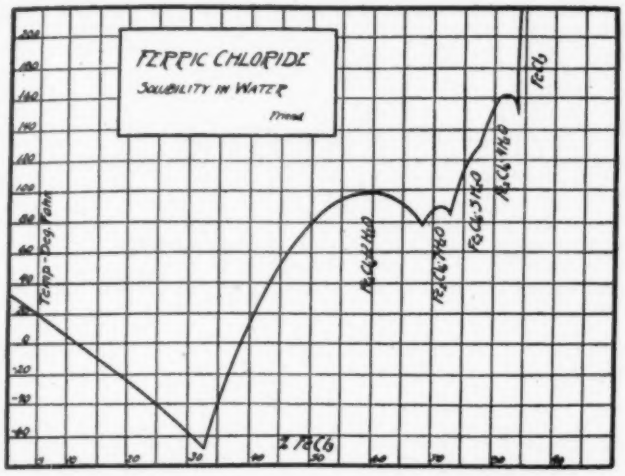
The steady advance in the utilization of chemicals in sewage treatment has created an increasing interest among engineers and municipal officials in the problems involved in their use.

The object of this article is to supply a concise outline of the more significant properties of ferric chloride and effective methods of handling and storing it.

At this time there are three commercial forms of ferric chloride available:

1. *Liquor*—An aqueous solution which is prepared to contain between 39 and 45 per cent $FeCl_3$ by weight to meet exact specifications.

2. *Crystals*—A definite crystal of the formula $FeCl_3.6H_2O$ containing 60 per cent $FeCl_3$ by weight.



Solubility of Ferric Chloride at Varying Temperatures. Note that a 45 Per Cent Solution will Crystallize at About 52 Degrees F.; a 33 Per Cent at Zero.

3. *Anhydrous*—A complete water-free form containing 98 per cent or more $FeCl_3$ by weight.

Liquid Ferric Chloride

Commercial ferric chloride liquor is a dark brown, somewhat oily appearing aqueous solution of varying concentrations. Obviously for the lowest transportation cost, the $FeCl_3$ content of these solutions should be as high as possible but concentrations are limited by crystallizing temperature conditions during transit or storage. To prevent crystallization the strength of solutions usually varies from 45 per cent in midsummer to 39 per cent $FeCl_3$ in midwinter. Average concentration of shipments over a period of several years has been 42 per cent.

Shipments are made in rubber-lined tank cars holding 8,000 gallons and averaging 40,000 pounds of dissolved $FeCl_3$ per car. The dome of the tank car is equipped with sump and center level discharges, a filling and air pressure pipe with gauge connection and a rubber disk safety valve which relieves at gauge pressures exceeding 25 pounds. The car is unloaded by attaching a rubber hose to the discharge connection and siphoning in case of low level storage tanks or by applying air pressure up to 25 pounds where a lift is required.

The maximum lift by air ejection is limited to 40 ft. If higher lifts are necessary a suitable pump should be provided.

Ferric chloride liquor (referred to in the trade as liquid ferric chloride) is easily handled and is usually the most economical form for use by the large consumer, who is reasonably near a source of supply. However, it has the disadvantage of requiring transportation costs on its 58 per cent (average) water content, railroad siding facilities, and storage tanks for one or more cars.

Storage Tanks

Except for its strongly corrosive nature, ferric chloride liquor offers no storage hazard, the only storage problem being provision of sufficiently large ferric chloride resistant tanks to store one or more carloads. *Ten thousand gallons should be the minimum storage capacity for plants using tank cars of ferric chloride.* Wood, reinforced concrete, or steel tanks lined with rubber with all exposed exterior surfaces painted with a ferric chloride resistant paint are the ideal containers. Covered tanks need not be sheltered but, in the case of unsheltered tanks, the strong liquor received during warm weather should be diluted in the storage tanks during the colder months to prevent crystallization. If possible, storage tanks should be elevated to permit the liquor to flow by gravity to dilution tanks or feeders, thereby confining all pumping to the simple air lift unloading operation from the car.

The concentrated ferric chloride solution taken from storage is preferably diluted to a 2 or 3 per cent solution when applied by one of the methods noted later in this article under "Feeding Equipment." Rubber-lined wood tanks under cover serve the Sewage Treatment Works of Milwaukee.

Crystal Ferric Chloride

Crystal ferric chloride is the oldest commercial form. As indicated in the accompanying graph, four hydrated crystals of ferric chloride can be formed; but, only the dodecahydrate, $Fe_2Cl_6.12H_2O$, (commonly written $FeCl_3.6H_2O$) is now commercially available. This material contains 60 per cent $FeCl_3$ by weight, is in the form of large yellow or brown lumps, has a melting point of 98.6° F., is slowly soluble in water at average tap temperatures, and is moderately hygroscopic.

The crystals are marketed in non-returnable, hardwood, paraffine-lined barrels of 55 gallons' capacity, which contain approximately 435 pounds of material. To prevent melting, and possible leakage, it is advisable to store barrels in single tiers under dry conditions at temperatures below 98.6° F. *The storage space required is approximately 70 square feet per ton of $FeCl_3$.*

Equipment for preparation of solutions and feeding crystal ferric chloride will be discussed in connection with anhydrous ferric chloride solutions, because of the close similarity of each.

Anhydrous Ferric Chloride

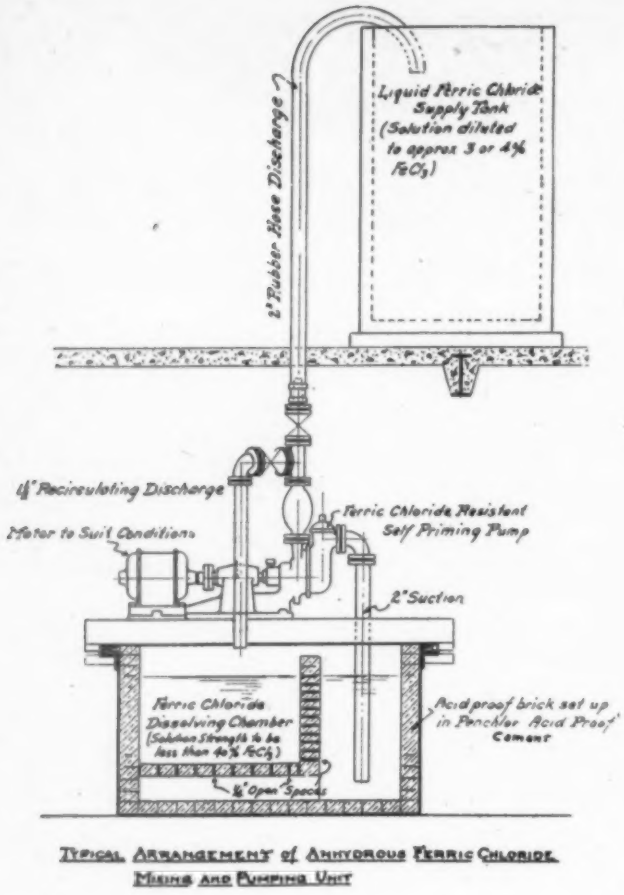
Anhydrous ferric chloride occurs rarely in nature, possibly the only source being the lava of Vesuvius. It takes the form of small greenish-black crystals with a melting point of 577.4° F., and is extremely hygroscopic, being readily soluble in water to 45 per cent concentrations at room temperatures above 55 degrees. The solubility curve for crystal ferric-chloride applies also to the anhydrous salt.

At present, the anhydrous form is being shipped in non-returnable steel drums holding 150 pounds of material. The drums, 15½ inches in diameter by 20 in height and weighing 10 pounds, are fitted with a 9-inch air-tight gasket and lid held in place by 4 screw bolts. These drums are convenient packages which may be stacked and stored indefinitely without deterioration. *Storage space required is approximately 40 cubic feet per ton of $FeCl_3$.*

Anhydrous ferric chloride has a decided advantage over the other forms by reducing transportation costs and storage space requirements 40 per cent or more. In addition, waste by leakage or deterioration is eliminated.

Preparation of Solution, Feed Methods And Equipment

The hygroscopic character of ferric chloride prohibits the use of dry feeds. The corrosive nature of solutions prevents the use


Liquid Ferric Chloride Supply Tank (Solution diluted to approx. 3 or 4% $FeCl_3$)
2" Rubber Hose Discharge
4" Recirculating Discharge
Motor to Suit Conditions
Ferric Chloride Resistant Self Priming Pump
2" Suction
Ferric Chloride Dissolving Chamber (Solution Strength to be less than 40% $FeCl_3$)
Acid proof brick set up in Perchlor Acid Proof Cement
4" Open Spaces

TYPICAL ARRANGEMENT of ANHYDROUS FERRIC CHLORIDE MIXING AND PUMPING UNIT

Sketch of Trouble Free Equipment and Method of Dissolving, Diluting and Feeding Ferric Chloride.

of ordinary piping and feeding equipment. A 20 per cent ferric chloride solution rapidly attacks the common metals and dehydrates wood, causing it to warp and shrink. Wood, or reinforced concrete, resists the action of weak solutions since excessive hydrolysis forms a protective hydrate coating. Equipment made of, or lined with, rubber, glass, Bakelite, or ceramic material, or the resistant metals such as Durichlor, or Hastelloy "C," will resist all concentrations of ferric chloride at normal temperatures. Rubber, glass, or ceramic materials may require additional protection against mechanical abrasion, or heat variation.

Feeding apparatus may vary from a simple solution tank with constant head orifice box to a modern "electric eye" controlled installation such as that used at the Chicago Sanitary District. The ideal and foolproof method of feeding involves 3 distinct steps: (1) Solution, (2) Dilution, (3) Application.

Dissolving Tanks

Solution tanks are necessary for dissolving either the crystal or anhydrous ferric chloride. Concentrations of less than 40 per cent are recommended to prevent crystallization and, in the case of anhydrous ferric chloride, high temperatures at the time of preparing the strong solution.

Solution strengths should be determined by adding a weighed quantity of ferric chloride to a definite volume of water as hydrometer measurements have proved to be unreliable. The tank should be at least partly filled with water before adding anhydrous ferric chloride to prevent the formation of the slowly soluble higher crystals and if the total contents of a drum are not added at one time the lid should be tightly replaced. Solution tanks of steel, reinforced concrete, or wood, lined with rubber and faced with acid-proof brick and cement, and of sufficient size to dissolve a 12 hour supply of ferric chloride, are preferable. A material rack, or compartment, and mechanical means of agitation are desirable features. Here illustrated is such a tank in connection with a pump which serves the dual purpose of agitating and lifting the concentrated liquor to the dilution tank above. The solution may be raised to the dilution tank by a vacuum lift if prepared.

Dilution Tanks

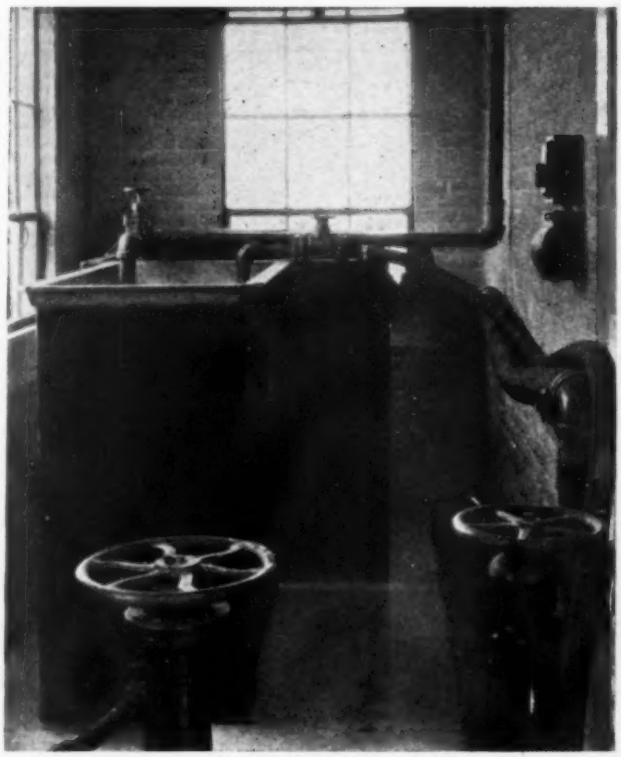
Dilution tanks are advisable for preparing and supplying uniform solutions to feeders. Concentrated solutions are diluted to 3 or 4 per cent $FeCl_3$ by adding gauged volumes of water and liquor. Experience indicates that stronger than 5 per cent solutions exhibit intense localized reaction on application and solutions weaker than 2 per cent may be appreciably hydrolyzed, especially by diluting waters of high alkalinity. Dilution tanks may be similar in construction to solution tanks without the acid-proof brick facing. Reinforced concrete tanks painted with a ferric chloride resistant paint, or large stoneware crocks are suitable. Other desirable features would include a mechanical stirrer, a graduated gauge rod, or glass, and a capacity for at least 4 hours' supply of solution. A tank with the depth exceeding other dimensions is preferable for more accurate gauging.

Solution Feeder

A positive displacement or a variable siphon head type of solution feeder is recommended for applying ferric chloride solutions. Several such corrosion resistant feeders, which have entirely corrected the uncertain performance peculiar to the old orifice type feeder, are on the market today. These feeders may be either manually or automatically regulated. Space does not permit even a limited discussion of all such feeders but following is a list of manufacturers: Galigher Company, Salt Lake City, Utah; Hills-McCanna Co., Chicago; Omega Machine Co., Kansas City, Mo.; Phipps & Bird, Inc., Richmond, Va.; Proportioneers, Inc., Providence, R. I.; Wallace & Tiernan, Inc., Newark, N. J.

Obviously, a gravity flow from solution tank to the final point of application is the ideal feeding arrangement. When lifting is necessary, any method which employs ferric chloride resistant materials may be used. Rubber-lined or hard rubber pumps, pipe and fittings are satisfactory for handling ferric chloride solutions at normal temperatures. Equipment made of Durichlor, or Hastelloy "C" is recommended for hot solutions.

For simple coagulation of sewages with ferric chloride, water purification practice for flocculation and sedimentation will give the best results. For sludge conditioning rapid agitation for 5 or 6 minutes followed by continuous filtration is preferable to the batch method.



Ferric Chloride Service Tank—Rubber Lined. Note Hose Connections and Hills-McCanna Co.'s "Saunders" Pinch-type Diaphragm Valves for Corrosive Liquids

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"The Only Safe Sewage is a Sterilized Sewage"

CHLORINATION OF SEWAGE

In the treatment of sewage, chlorination is used to advantage for all of the following important purposes: (1) Disinfection; (2) Odor control; (3) Corrosion and concrete disintegration control; (4) B.O.D. reduction; (5) Improvement of settling and control of foaming; (6) Conditioning of return supernatant liquid; (7) Prevention of sludge bulking; (8) Sludge conditioning; (9) Adjunct in chemical precipitation; (10) Trade waste control.

DISINFECTION OF EFFLUENT

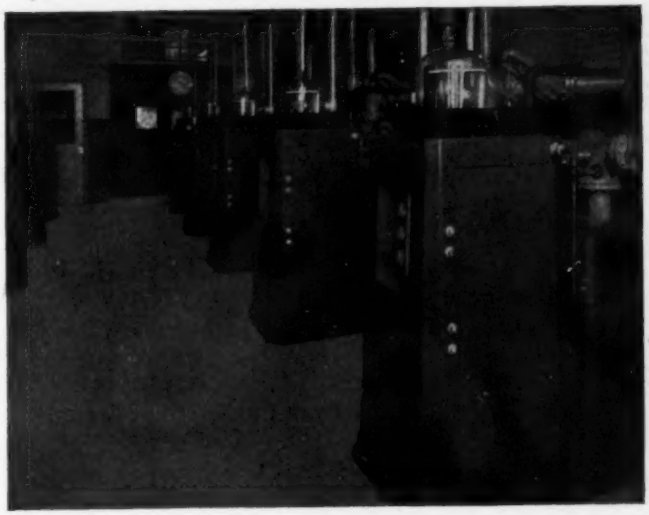
Regardless of the preliminary processes of sewage treatment, disinfection of the effluent before discharge is of vital importance, for the protection of water supplies, bathing beaches and shellfish propagation beds.

ODOR CONTROL

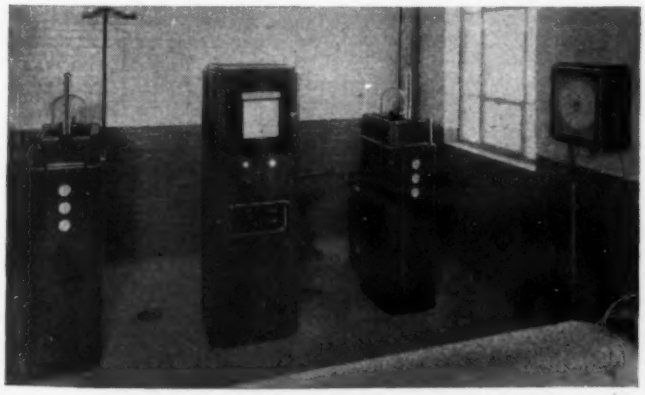
Chlorination is the most effective method for the control of odors from sewage treatment works, long outfall sewers and other disposal plant adjuncts. By preventing the formation of hydrogen sulphide, chlorination not only checks the development of odors, but also effects economies in operation.

B.O.D. REDUCTION

It is essential that the B.O.D. (bio-chemical oxygen demand) of the sewage effluent be kept low to avoid depletion of oxygen in the stream into which the effluent is discharged. Otherwise fish and other water life will be destroyed, the stream will have a foul appearance and odor nuisance will result. Hot weather greatly increases the rapidity of bacterial action in the sewage and its decomposition resulting in increased B.O.D. Since chlorine is a powerful oxidizing agent, it is very effective for reducing B.O.D. and is widely used for this purpose.



Five W&T Master Visible Vacuum Chlorinators operating at Bird Island Sewage Plant, Buffalo, N. Y.



An installation of W&T potential control chlorinators. Chlorine is automatically fed at a rate determined by variations in quantity and quality of sewage. Note Chlorine Flow Recorder.

USE OF IRON SALTS

Various iron salts are frequently employed in sewage treatment for such purposes as odor control, chemical precipitation, and sludge conditioning. Wallace & Tiernan furnish chemical feeders for applying these salts in any desired manner.

CHLORINE FLOW RECORDERS

W&T Chlorine Flow Recorders meet the need for continuous automatic flow recording. They provide a valuable record of treatment, aid in plant supervision, and in analysis of results.

TECHNICAL SERVICE

The services of technically trained men from our Engineering and Research Departments are always available to study and recommend equipment for any phase of sewage chlorination or industrial waste treatment.

Their recommendations will be based on experience secured in making more than 30,000 installations of Wallace & Tiernan chlorine control equipment in all parts of the world, for the sterilization of water supplies, sewage treatment, swimming pool sanitation, and for various industrial applications. Such recommendations will involve no obligations.

Write for Technical Publication No. 243.

DOSAGE CONTROL IN SEWAGE CHLORINATION

By GEORGE E. SYMONS
Assoc. Editor, Water Works and Sewerage

IN SEWAGE treatment works employing disinfection by chlorination, some control of chlorine dosage is necessary to meet the varying needs. The larger the plant the more important is such control, both from the standpoint of economy and bactericidal efficiencies. Efficient and non-wasteful usage is important and there is particular merit in efficient application control in the sanitary field.

Quite obviously, any system of continuous chlorine dosage control to meet variable conditions will produce the most efficient results[1]. Lacking continuous control, some "programmed step by step method of chlorination"[1] offers the best substitute. The time interval of the steps may be dictated by the size of the treatment works, the variables of chlorine demand and flow, the plant personnel and operation routine, the desired results, and the economy involved. The effect of all these factors must be considered in the development of the control system.

A Control System

In the development of a control system, it is necessary to set up certain definitions, techniques, dosage curves, control tests, and factors. These are essential to meet all possible variations of chlorine demand by hours or seasons, and with temperature and storms and industrial wastes as well as with pumping schedules and other operating conditions.

Definitions

Chlorine Demand: The parts per million (mg. per liter) of chlorine required to be added as *chlorine water* (1 mg. Cl_2 per ml.) to produce 0.1 p.p.m. of residual chlorine after 15 minutes contact of the chlorine water and sewage.

Residual Chlorine: That chlorine added to water or sewage which is available, after a definite contact time, for reaction with orthotolidine or potassium iodide. It is the surplus of chlorine added which is not required in satisfying the chlorine demand of the liquid chlorinated.

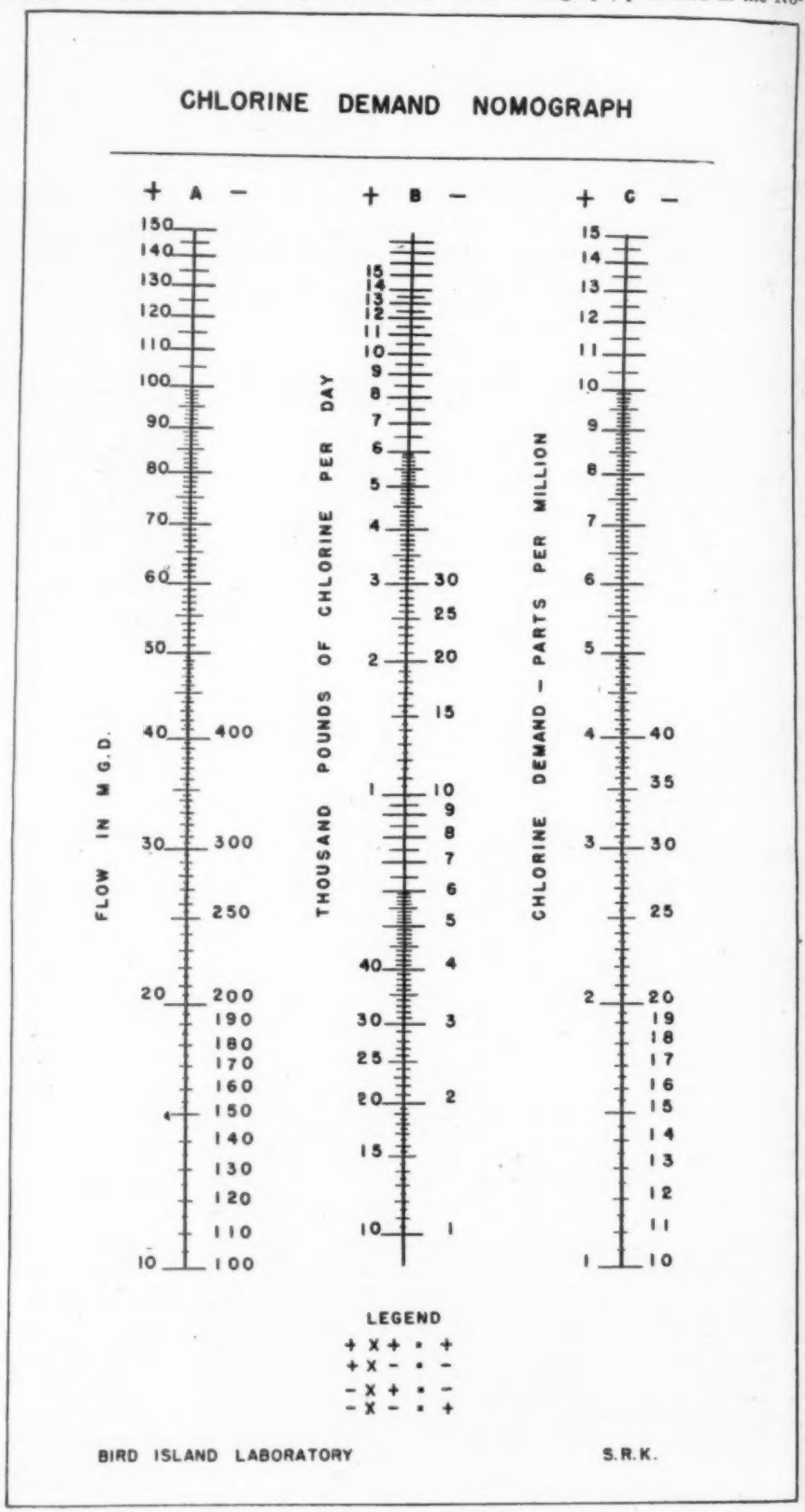
Spot Test: The determination of the residual chlorine in chlorinated liquids by the addition of 3 drops of orthotolidine reagent to 1 ml. of sample on a conventional laboratory spot plate.

Immediate Chlorine Demand (I.C.D.): The parts per million (mg. per liter) of chlorine required to be added as chlorine water (1 mg. Cl_2 per ml.) to produce 0.1 p.p.m. of residual chlorine when a spot test is made on the sewage immediately after the addition of the standard chlorine water. This value is indicated by the abbreviation I.C.D.

Reagent Factor: The factor used to calculate p.p.m. of chlorine demand from the amount of chlorine water added to the sample. This factor is calculated from the size of the sample (in ml.) used for the determination, and the strength of the chlorine water in mg. per ml. Reagent factor × ml. of chlorine water = p.p.m. of chlorine demand (C.D.).

Chlorine Demand Rate per 24 Hours: The feeding rate, in terms of pounds of chlorine added per day, required to satisfy the chlorine demand of any given flow of sewage with a particular chlorine demand, i.e., the rate of feed required in lb./24 hrs. to meet the chlorine requirement for the flow and sewage strength (chlorine demand) existing at any hour.

Chlorine demand rates per day equal p.p.m. of C.D. × flow in m.g.d. × 8.34. This value can be determined directly from the Multiple Chlorine Demand Nomograph, published in the No-



vember, 1940, issue of this magazine[2]. It is an adaptation of a single nomograph for chlorine demand originally developed by Everett C. Handorf[3].

Chlorine Demand in Pounds per m.g.: Lb. per m.g. = p.p.m. of C.D. × 8.34

Dosage Factor: The factor by which the chlorine demand (lb. per m.g.) at any particular hour must be multiplied to determine the chlorine dosage rate (lb. per m.g.) for the following hour.

The use of this factor may be necessary in the control of the chlorine dosage because frequently the time required for collecting the samples and making the chlorine demand test makes it impossible to ascertain the demand until after the sewage represented by the sample has been chlorinated. This factor is affected by the time of day, season of the year (temperature of sewage) and storm flows.

Dosage Rates: The number of pounds of chlorine to be added to each million gallons of sewage pumped during the succeeding period until another adjustment is made.

The Determination of Chlorine Demand

Approximately a 5 pint sample of sewage is collected. All samples should be delivered immediately to the laboratory for analysis. Residual chlorine tests should be made on samples of sewage after chlorination. The chlorine demand is determined on samples, as follows:

(1) *Reagents:* Chlorine water made by passing chlorine gas through distilled water or tap water until 1 ml. contains approximately 1 mg. of chlorine. Standardize by titration with thiosulphate. Orthotolidine indicator solutions as recommended in the committee report on "Control of Chlorination[4]."

(2) *Procedure:* Measure out 5 portions of sewage to be tested, using 200 to 250 ml. samples. To the first of these samples add the standard chlorine water, 0.5 ml. at a time (equivalent to approximately 2 p.p.m. of chlorine) mixing by gentle agitation until a spot plate test, using 3 drops of orthotolidine solution and 1 ml. of the sample, give a detectable yellow color[5], but not necessarily a non-fading color. Call this the immediate chlorine demand (I.C.D.).

Using the I.C.D. as the basis of dosage, add reagent chlorine water to the other flasks in increasing quantities, using increments of 0.2 to 0.5 ml. above the I.C.D. Gently mix the contents of all flasks and allow to stand for exactly 15 minutes. At that time determine the residual chlorine in each flask by a spot test. (It may generally be expected that the I.C.D. is somewhat less than the 15 min. C.D.)

Usually 1 minute is sufficient for the development of maximum color. Use standards made from chlorine water or permanent standards made from copper sulphate and potassium dichromate solutions. These latter must, however, be adjusted to match the hue produced by chlorine water and orthotolidine in a spot plate.

When the maximum color has developed in all spots determine the dosage which has produced 0.1 p.p.m. of residual chlorine or thereabouts. In the absence of standards for comparison, pick the spot with the minimum color. This color is approximately 0.1 p.p.m. In some cases it may be necessary to interpolate in order to determine the amount of chlorine reagent necessary to produce the readable color.

(3) *Calculations:* Calculate the chlorine demand from the amount of chlorine water used and the reagent factor, as illustrated previously. When using 250 ml. of sample; ml. of chlorine solution × mg. of chlorine per ml. × 4 equals p.p.m. chlorine demand (C.D.), or prepared tables may be used for different sized samples and different reagent factors.

For the data records the Chlorine Demand Rate in pounds per 24 hours is determined from the chlorine demand in p.p.m. and the registered sewage flow at the time of the sampling. The Chlorine Demand Nomograph[2] (see cut) is used for this calculation and the resulting value is utilized in weighting the 24 hour average chlorine demand in parts per million.

Directions for Using the Nomograph

In reading the nomograph to determine the chlorine demand or dosage in 1,000 pounds per day from the p.p.m. and the flow in m.g.d., a simple algebraic rule for multiplication must be remembered, viz., plus times plus equals plus, plus times minus equals minus, and vice versa, and minus times minus equals plus. Therefore, if the A+ and C+ scales are used, read on B+, or if A+ and C— are used, read on B—, or if A— and C— scales are used, read B+.

The use of these scales in this manner allows a range of from 1 part per million and 1,500 m.g.d. to 150 p.p.m. and 10 m.g.d. with the thousand pounds per day varying between 0.1 and 1,500. Factors or multiples of 10 extend the range in both directions. By the use of factors or multiples, the readings can always be kept in the area most easily read. A factor of 1,000 will easily convert thousand pounds per day to pounds per day. Scales "A" and "C" can be used for quantities rather than rates per day, in which case Scale "B" reads in quantities rather than rates per day.

The nomograph has other applications than in chlorine application. It may be used to calculate pounds or thousand pounds of solids in sewage, or sludge, from the analysis and the volume, and for other purposes.

This type of nomograph has several advantages, its use is simple, it gives relatively accurate readings, its system and use can be easily taught to routine control, and it eliminates much calculation where the chlorine demand determination is made frequently.

Determination of Chlorine Dosage

After the determination of the chlorine demand on the samples, the results must be translated into operation control. The data available for this use include the following:

a. The 15-minute chlorine demand of the raw sewage.

b. The residual chlorine or chlorine demand (as the case may be) of a sample of sewage after chlorination.

Obviously all of these data represent conditions that have passed and therefore some relation between such data and future hours has to be developed. The average or normal expected relation of the chlorine demand of one hour to the next for raw sewage may be determined from statistical study of the hourly variations in chlorine demand[6]. Inasmuch as these relations vary with seasonal temperatures, it is necessary to develop several series of factors to apply at the different seasons. Typical factors as developed at Buffalo, N. Y.,[2] are listed in Table 1 which shows the percentage by which the chlorine demand of the previous hour must be multiplied to obtain the chlorine demand for the hour desired. For practical purposes these percentages were rounded off to factors containing one decimal place as shown.

If there were no other factors involved, it would be possible to calculate the *Chlorine Dosage Rate* in pounds per million gallons for the succeeding hours from these factors and the chlorine demand in p.p.m. of the sample of the previous hour. However, it has been found in practice that there is a seasonal empirical factor that must be applied to these calculations. In the winter time it is found that something less than the calculated

TABLE I

FACTORS FOR DETERMINING CHLORINE DEMAND AT ANY HOUR FROM RESULTS OF PREVIOUS HOUR

Season	Jan., Feb., Mar.		April		May		June, July, Aug., Sept.		Oct., Nov., Dec.	
Hour	Per Cent	Factor	Per Cent	Factor	Per Cent	Factor	Per Cent	Factor	Per Cent	Factor
8:00 A.M.	103	1.0	97	1.0	100	1.1	102	1.0	98	1.0
9:00 A.M.	111	1.1	116	1.2	107	1.1	113	1.1	112	1.1
10:00 A.M.	112	1.1	114	1.1	111	1.1	102	1.1	111	1.1
11:00 A.M.	113	1.1	115	1.2	122	1.2	116	1.2	118	1.2
12:00 Noon	102	1.0	111	1.1	110	1.1	105	1.0	104	1.0
1:00 P.M.	100	1.0	96	1.0	93	0.9	105	1.1	100	1.0
2:00 P.M.	98	1.0	94	1.0	97	1.0	99	1.0	103	1.0
3:00 P.M.	102	1.0	100	1.0	98	1.0	101	1.0	103	1.0
4:00 P.M.	106	1.1	93	1.0	109	1.1	100	1.0	100	1.0
5:00 P.M.	100	1.0	100	1.1	97	1.0	100	1.0	103	1.0
6:00 P.M.	96	1.0	92	0.9	98	1.0	97	1.0	99	1.0
7:00 P.M.	96	1.0	100	1.0	100	1.0	100	1.0	96	1.0
8:00 P.M.	92	0.9	98	1.0	98	1.0	97	1.0	93	1.0
9:00 P.M.	100	1.0	89	0.9	95	0.9	95	1.0	97	1.0
10:00 P.M.	94	0.9	95	1.0	96	1.0	94	0.9	94	0.9
11:00 P.M.	104	1.0	95	1.0	100	1.0	100	1.0	103	1.0
12:00 Mid.	94	0.9	97	1.0	96	1.0	95	1.0	97	1.0
1:00 A.M.	98	1.0	97	1.0	96	1.0	102	1.0	96	1.0
2:00 A.M.	98	1.0	100	1.0	98	1.0	98	1.0	97	1.0
3:00 A.M.	98	1.0	100	1.0	98	1.0	98	1.0	97	1.0
4:00 A.M.	92	0.9	94	0.9	93	1.0	93	0.9	93	0.9
5:00 A.M.	97	1.0	94	0.9	93	1.0	94	0.9	100	1.0
6:00 A.M.	97	1.0	96	1.0	97	1.0	94	1.0	93	1.0
7:00 A.M.	103	1.0	111	1.1	103	1.0	102	1.0	96	1.0

chlorine dosage from laboratory tests will satisfy the actual demand of the sewage in the plant and will produce a residual chlorine content in the sewage 15 minutes after dosage. In the summer the reverse is true. Therefore, a series of *Dosage Fac-*

TABLE II

FACTORS FOR DETERMINING CHLORINE DOSAGE

Seasonal Dosage Factors for the Determination of the Chlorine Dosage for Any Hour from the Analysis of a Sample of the Previous Hour

Season Hour	Jan., Feb. and Mar.	April	May and Dec.	June and Nov.	July and Oct.	Aug. and Sept.
8:00 A.M.	0.9	0.9	1.0	1.1	1.2	1.3
9:00 A.M.	1.0	1.0	1.1	1.1	1.2	1.3
10:00 A.M.	1.0	1.1	1.2	1.2	1.3	1.4
11:00 A.M.	1.0	1.1	1.0	1.2	1.3	1.4
12:00 Noon	0.9	1.0	0.9	1.1	1.2	1.3
1:00 P.M.	0.9	0.9	0.9	1.0	1.1	1.2
2:00 P.M.	0.8	0.8	0.9	1.0	1.1	1.2
3:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
4:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
5:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
6:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
7:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
8:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
9:00 P.M.	0.6	0.7	0.8	0.9	1.0	1.1
10:00 P.M.	0.6	0.7	0.8	0.9	1.0	1.1
11:00 P.M.	0.6	0.7	0.8	0.9	1.0	1.1
12:00 Mid.	0.5	0.6	0.7	0.8	0.9	1.0
1:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
2:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
3:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
4:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
5:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
6:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
7:00 A.M.	0.7	0.8	0.9	1.0	1.1	1.2

tors to fit operating conditions were developed for the various seasons as shown in Table II, for Buffalo.

Having determined the demand of the raw sewage in p.p.m., then by the use of the various tables the *Dosage Rate* in pounds per million gallons can be calculated for the succeeding hour. The value multiplied by the flow gives the setting for the chlorinators accordingly for the succeeding hour.

As might be expected, there are exceptions which will not fall into this regular routine. The tests on the chlorinated effluent samples are an aid in checking operation and exceptional conditions. Any continued over-or-under-chlorination calls for adjustment of the dosage factor. Likewise, the test on the effluent may indicate a dosage too low to produce effective disinfection[7].

Special Conditions Affecting Chlorine Control

To meet the special conditions which arise by virtue of any one or more of a number of factors including storms, pumping schedules, and others, special rules must be developed from practical and theoretical considerations.

These rules must consider such items as, over or under-dosages, sudden changes in rate of flow because of changing pumping schedules, desired disinfection of storm flows, abnormal chlorine demands caused by industrial wastes, false end-points, or effect of digestion tank supernatant liquor.

Maintenance of Chlorination Equipment

Mechanical difficulties with chlorinators may include some unusual occurrences, repairs, or cleaning.

For example, during the summer months, insects prevalent in the locality, may add to the difficulties of operation when the insects alight in the water of the bell jar tray and are drawn into the apparatus plugging the water lines. Uneven pressure exerted on the rim of the jar by the stops being too tight may cause strain, and sudden differences in temperature between gas and water contribute to the cracking, but greater care and attention to these details will reduce this breakage.

Accumulation of chlorine "taffy" in the evaporators may result in sudden discharge into the bell jars at times. Some of this material is high in ferric chloride and the fact that pipe lines have been found to contain ferric chloride indicates a possible reverse migration of water. This migration may occur due to back pressure in idle chlorinators.

It has been observed that chlorine solution backing up into idle machines from the discharge lines occurred apparently because of chipping of the glass ball check valves in the lines from the individual chlorinators. The corrosive solution causes disintegration of the chlorine needle valve stems, thereby requiring more replacement of this item than any other. It is, therefore, expedient to keep idle machines operating under a slight vacuum, and frequently to drain all tubes and valve chambers to insure removal of the corrosive solution. Pressure reducing diaphragms have had to be replaced because they developed fine pin holes, possibly due to corrosion induced by the suspected reverse migration of water.

Cleaning of various items may be by several methods. Carbon tetrachloride or acetone to clean bell jars of "gum"; steam followed by hot air or acetone to clean iron pipe lines carrying liquid chlorine.

In summarizing, it should be pointed out that the details of this method of dosage control are subject to revision as chemical, bacteriological, and operating data are obtained, but the fact that the disinfection results[8] have been most satisfactory indicates that the principles of the system are basically sound.

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KILLING ROOTS IN SEWERS WITH COPPER SULPHATE

By J. W. McAMIS

Superintendent Water Works and Sewerage, Greenville, Tenn.

Roots give a great deal of trouble in the smaller sewers, by causing stoppages wherever they may happen to find an entrance into the pipes carrying domestic sewage.

For four or five years now we have been using copper sulphate to combat this trouble.

We have a man whose duty it is to visit each manhole in the system at least once each month, looking for stoppages. He carries along on these trips a small bag or bucket of copper sulphate and drops a small handful of crystals down into the flowing sewage wherever he finds that the stoppage is downstream.

After a reasonable amount of experience in this work a man can tell pretty well where trouble is to be expected in the near future, by the nature of the flow of the sewage and by the conditions in the bottom of the manhole.

In cases where stoppage is due to roots, sewage will back up into the next manhole above during periods of greatest flow during the day and will recede during periods of low flows. This condition may exist for days or possibly weeks before the sewage begins to overflow the top of the manhole and run into the street. By throwing in the copper sulphate crystals *while the sewage is still flowing*, a sufficient concentration of the poison will usually reach the seat of the trouble to eliminate it before the stoppage is complete.

At Greenville, we have the same man doing this work that looks after the disposal plants and he tells me that he can predict almost exactly when the balls of roots will turn loose and come down to the treatment plant following the copper treatment.

Since we have been using this scheme it is a rare day when we have to send out a truck with sewer-rods and other equipment to open up a stopped sewer.

Regarding the exact quantity of the sulphate required for good results, I have attempted no determination of the necessary concentration of copper sulphate. However, it is my opinion that the length of the contact period is a more important factor than the actual concentration of the copper sulphate. To illustrate; the ideal condition seems to be where a small flow of sewage, say two to five g.p.m., is just trickling through a mass of roots. In a case like this a small handful of the chemical applied in the manhole just upstream from the stoppage will do the trick.

If the flow is greater, as determined from looking in the manhole just below the stoppage, greater quantities and possibly repeated applications would be necessary. If it is kept in mind that it is time of contact that is important, rather than the amount of copper sulphate, no trouble should be experienced in carrying out this operation.

Another important point to remember is that it is useless to apply the copper sulphate in a sewer that is completely stopped, for unless there is at least a small flow of sewage through the obstruction there is no chance for contact between the roots and the copper solution. Sewer rods would be the only remedy here—at least to start some flow through and allow the copper to reach the roots. (Since it is only necessary to kill the small root which enters the sewer, and not the great mass of roots branching from it, the important factor is that of reaching the feeder root with the killing chemical. Then, the flow pulling on the large heavy "brush," causes the weakened base root to break. Prechlorination of sewage has been found to produce the same results on root infected sewers but is not so simply applied as the copper treatment.—Ed.

REDUCING COST OF SLUDGE REMOVAL

Experiences at Aurora, Ill., with a "Saddle-Bag" Tractor

By WALTER A. SPERRY, Superintendent
The Aurora Sanitary District,
Aurora, Illinois

DURING the summer of 1940 the Aurora Sanitary District constructed eight new sludge drying beds under a W. P. A. contract. This increased the sludge drying area from 50,000 to 96,250 square feet, which gave 1.44 square feet per capita on the original design basis of 67,000 population and 1.96 square feet per capita on the basis of the present population of 49,000. This increase was desirable due to the frequency of winter cleans caused by increased loadings on the plant and the addition of secondary sludge to the digesters in 1937.

Sludge Removal Methods Evaluated

New drying bed construction involved the selection of a method for removing sludge. Two factors entered in. The first was the cost of trackage versus a more modern method of mechanical removal. The second revolved around the sponsor's credit in the W. P. A. set-up for the disposal of some 3,500 cubic yards of excavation. If contractor's equipment was hired to do this work it would cost more than if the sponsor had in hand dirt moving machinery where the only expense would be gasoline, motor oil and the operator's wages. This led to the consideration of abandoning tracks in all beds and substituting therefor the "saddle-bag" tractor originally planned by Mr. W. B. Walraven of Springfield, Ill., and described by him in an article, "A New Device for Handling Dried Sludge," in *Water Works and Sewerage* of February, 1934. General investigation indicated that this was, by far, the best device available. Some pressure was brought to bear to adopt a self-propelling bucket elevator to pick the sludge from the beds and discharge it to a following truck. Also it was urged to purchase a tractor with a yard shovel attachment in front, similarly working with a truck.

These devices were not suitable, first, because of the damage to the sludge beds in attempting to pick up mechanically a thin layer of material from a relatively thin layer of sand without disturbing the gravel underneath; second, because of the bulk of the equipment and the cutting up of the bed by both the tractor and truck; third, a truck was not suited to travel over the sludge storage pile; fourth, all of these devices were expensive and of no value for any work about the plant; and fifth, the required space for storage in the interim period was not available.

Advantages of the Crawling Tractor

The Springfield tractor, on the other hand, was self-contained. Equipped with caterpillar treads enabled it to travel over the sludge storage pile under quite adverse conditions, i.e., when wet and soft.

Due to its ability to mount and crawl over the storage pile, the "saddle-bag" tractor appeared to be especially useful in making the most of limited storage areas. It has also proved useful for the disposal of grit from the screen house to the storage space. The machine can be equipped with a bull-dozer for snow problems in the winter, for trimming the sludge pile and for grading gravel roads or pulling stumps. The tractor required small storage space and has generally offered all the facilities of a man carrying two buckets where the load could be transported and deposited anywhere the feet could walk.

Considering its adaptability and general usefulness, it seems surprising that but three of these machines are in use to date. The original one is at Springfield, the second at Mansfield, Ohio, and the third here at Aurora, Ill.

Trackage for the new beds would have cost in the neighborhood of three thousand dollars ($3,000). The tractor equipped with the side bins cost two thousand, two hundred and sixty dollars ($2,260). Against this cost its temporary use as a construction unit in building the sludge drying beds saved the Aurora Sanitary District about sixteen hundred dollars ($1,600) over rented equipment for the construction period.

The Unit

The tractor (see cut) is an "M" type Allis-Chalmers caterpillar type machine. It is driven by a 32.4 H.P. engine with four forward speeds, is equipped with starter, and weighs 6,500

The Tractor Being Loaded During a Winter Cleaning Operation
The hard, frozen sludge is first broken up by the "breaking gang," and thereafter easily loaded into the "saddle bags." Note the comfortable loading height of these side-bins.

pounds. Equipped with the bins, it is about 8 feet long, 7 feet wide and 6 feet high over-all. The bins, which have a combined capacity of 3 cubic yards, add another 1,500 pounds for a total weight of 8,000 pounds. It has a bearing of 1,530 square inches. With full bins this gives a pressure per square inch of from 7 to 9.5 pounds, depending upon the moisture content of the sludge. The bins are constructed of 8 gauge metal and the whole device is of such strong and sturdy construction that its life will be many years. The original machine purchased in 1932-33 is still in use at Springfield and in good order.

Performance Records

Before purchase of the tractor, in the period July, 1939, to May, 1940, inclusive, 4,055 cubic yards of sludge were removed from the Aurora beds to the storage pile at a total cost of $2,095.51, or 51.6c per cubic yard. The unit cost varied from 30.6c to 67.7c per cubic yard, as between summer and winter conditions. For this period the standard crew then hired for the cleaning jobs consisted of a team at $10 per day and seven men at 45c per hour. This gave us a daily hired labor cost of $35.20. Experience showed that three 1 cubic yard cars, two men to a car, gave the right balance of work for the team and Fresno scraper used.

The tractor was purchased and went into use in June, 1940. Between June, 1940, and March, 1941, inclusive, 4,933 cubic yards of sludge were removed to the pile at a total cost of $1,057.59, or 21.4c per cubic yard, to which should be added two cents per cubic yard for tractor oil and gasoline. The tractor crew consisted of four men at 45c per hour, or a total cost of $14.40 per day. This is a difference of $20.80 per day for hired labor between the two methods. Note that the gang foreman in the first case is the tractor operator in the second case. He is a plant employe on the regular payroll and not included in either cost estimate. This indicates a saving of 54.8 per cent for the new method.

At the time the tractor was purchased it was assumed that the saving would be in the cost of the track and the reduced price due to the temporary rental to the Government, and that the time of sludge removal might be extended since but four men were lifting sludge against six with the old method. The interesting surprise was that four men and the tractor do at least 90 per cent as much work as six men, due to the fact that the trip to the storage pile is but once for every 3 cubic yards, whereas, formerly each 1 cubic yard lot was pushed by car to the pile by its two man crew, with "waits" for any car ahead to clear switches.

During interim periods the tractor is stored in the screen house and is used almost daily to remove grit. A bull-dozer blade is being planned for permanent mounting for clearing snow from the plant driveways, trimming the storage pile, and for maintenance of the gravel roadways.

Two Minor Objections Appear

Two minor objections to the tractor are that a little more care must be taken to keep the sludge beds well sanded against the disturbing effect of the tractor cleats. The second objection developed this winter when it was discovered that the physical condition of the operator was affected due to shock and jar caused by the frozen state of the ground. Happily this was satisfactorily corrected by the purchase and use of a wide leather belt such as is used by motorcyclists and truck drivers to support the abdominal region.

INSTRUCTIVE WALL PANEL FOR TREATMENT PLANTS

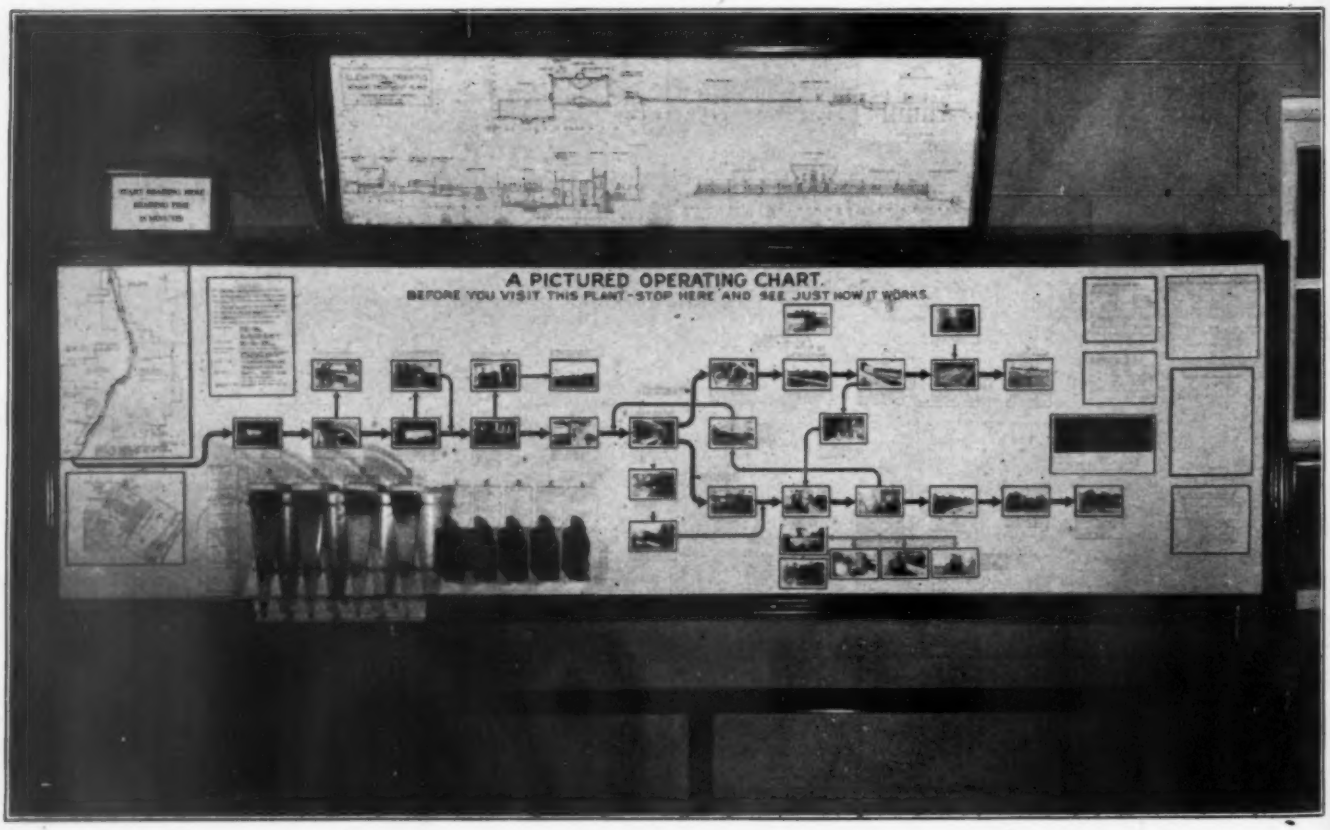
A Picturized Operating Chart with Specimens Attached

AT the Sewage Treatment Plant at Aurora, Illinois, the visitor runs smack into this wall panel designed by Walter A. Sperry, Plant Supt.

The sign reads—"Before inspecting the plant stop here long enough to see how it works. But 15 minutes is required to read all captions."

We are reproducing this picture of Aurora's instructive chart because it seems an ideal method of giving the visitor a preview of what he is to see in looking over the works. Further than that, it is used frequently for the purpose of instructing school classes, Boy Scouts and Girl Scouts who visit the plant.

Photographs are used to show the relationships of each plant unit to the other and its functions are indicated by live specimens of crude, settled, filter effluent and final plant discharge in Imhoff Cones. Samples of sludge "before and after" are exhibited and also petri dishes showing what happens to the bacteria. The whole thing is a great idea and, what's more, saves many words.



SLUDGE AS FERTILIZER

Its Place and Use in Vegetable Gardening

By LE ROY W. VAN KLEECK
Senior Sanitary Engineer
Connecticut State Dept. of Health, Hartford, Conn.

BECAUSE the war made it imperative that full use be made of all of our natural resources, the State Department of Health of Connecticut discussed the use of sewage sludge for fertilizing lawns, flower gardens and food crops.

Only Digested Sludge Recommended

When raw sewage solids are settled in tanks at sewage plants and stored under controlled conditions in special tanks called "digesters" (either heated or unheated) for considerable periods, it is called digested. The digestion of sludge involves a biochemical process in which the organic matter remaining in the sludge is in a more stable form. Whereas raw sludge is generally brown in color, lumpy, watery, and has an offensive odor, digested sludge is black in color, homogeneous, has the consistency of thinned molasses, and gives off a tarry or gassy odor which is not offensive. Raw sludge is odorous, has a high grease content, tends to make soils acid, is a potential carrier of pathogenic bacteria, and is not humified for soil use. The use of raw sludge in any form is not recommended.

Liquid digested sludge contains from 85 to 98 per cent water and is rarely used as a fertilizer. Principal objections are, first, the large quantity of fluid bulk that must be transported; secondly, the difficulties of application to the area to be fertilized; and, thirdly, the greater likelihood of objectionable odor. Instead, sludge is generally utilized following partial dewatering by draining it on beds of sand, pressing, centrifuging or vacuum filtration. The partially dried sludge is then referred to as "sludge cake," and ordinarily contains 70 per cent or less of moisture. Such cake is dry enough to be shoveled and spread like manure or moist soil.

Fertilizing Value of Digested Sewage Sludge

A comparison based on chemical analysis of digested primary sludge and related materials as reported by various investigators is afforded in the accompanying table.

TYPICAL CHEMICAL ANALYSES OF SEWAGE SLUDGE, MANURES, AND COMMERCIAL FERTILIZERS

	Total Nitrogen % (Dry Basis)	Total Phosphoric Acid % (Dry Basis)	Total Potash % (Dry Basis)
Digested Sludge (Average of samples from a number of sewage plants in Connecticut)	1.7	1.5	0.15
Horse Manure	2.2	1.10	1.6
Sheep Manure	1.8	1.52	3.0
Poultry Manure	3.6	3.5	1.9
Common Garden Commercial Fertilizer	4.0	9.0	10.0

It will be noted that digested sewage sludge compares favorably with the ordinary run of manures. Its principal deficiency is in potash. The nitrogen in sludge has been shown to be available over a long period (generally at least two years) and there is, therefore, no danger of so-called burning of crops.

The chemical analysis of sludge does not, however, tell the entire story. Primary digested sludge has its greatest use as a soil conditioner, constituting as it does a valuable source of humus. Generally, about 50 per cent of the dry weight of sludge is humus. Sludge is not a complete food for plants as commercial fertilizers are and cannot be expected to serve as an all-purpose plant food. It should be supplemented by the use of commercial fertilizers. Its application, however, has a favorable effect on soil structure. Soils repeatedly planted to growing crops require the organic humus present in manures, peat moss, green cover crops, and sludges. In addition, sludge contains soil improving and growth promoting values by replenishment of organic matter and because the minor elements it contains are needed by plants.

Another significant point, not revealed in the chemical analysis of digested sludges, is the comparative freedom of such sludges from weed seeds which are largely destroyed in the digestion process. On the other hand, most manures, unless well rotted, contain numbers of weed seeds which prove very objectionable, particularly when they are spread on lawns. Tomato seeds and a few of the cucurbits will sprout in sludge, but they are not ordinarily troublesome.

When used continuously on land, sludge not conditioned with lime tends to acidify the soil. Hence, corrective measures must be taken every three or four years to avoid damage to plants requiring a neutral or near neutral soil by checking acidity, caused largely by the breakdown of the greases and fats present in sludge. Judicious applications of ground limestone or hydrated lime will correct such acidity.

Methods of Applying Digested Sludge and Hygienic Considerations

Sludge may be applied as a top dressing in the case of trees or lawns; in the hill in the case of melons, squash, or other vine crops; or spread, then plowed or spaded into the soil. When used as a top dressing, it should not be applied too thickly, especially on lawns, or it may choke the growing vegetation. Recommended amounts are listed in an accompanying table. Sludge may be applied when the ground is frozen or covered with snow. In such cases it is raked and pulverized into the soil in the spring. Grinding sludge cake with machines greatly enhances its application as a top dressing. Except where applied to grass, trees, shrubs or perennial beds, sludge should be placed in the hill or plowed under in the fall or early spring before planting the crop.

Digester sludge is safe from the health standpoint if mixed with the soil and not applied to the growing crop. It is safer not to plant root crops eaten raw (examples, carrot or radish) or vegetables grown in close contact with the soil and eaten raw (examples, lettuce, celery, onions) in ground recently fertilized with sewage sludge.

The digestion of sludge, together with the commoner methods of de-watering such as air-drying or vacuum filtration (in which case most sludges are conditioned with lime, giving a high enough pH to kill great numbers of bacteria), afford sufficient protection against intestinal diseases. It is also desirable, of course, to use reasonable care in handling it. A special committee of the Federation of Sewage Works Associations reporting on the "Utilization of Sludge as a Fertilizer" states: "The committee knows of no case of sickness traceable to the use of digested sludge or activated sludge." (In the latter case the sludge has been subjected to heat drying which effects post irrigation along with the drying.)

Amount of Digested Sludge to Use

While an excess of sludge will rarely do harm, except in cases of outright mechanical smothering of growing things, the following suggestions for its application have been made by various investigators:

For orchards—16 tons sludge cake per acre (or about 11 cu. yds. per acre).

For grass—10-20 cu. yds. per acre (or 0.6 to 1¼ cu. ft. per 100 sq. ft. of soil).

For vegetables, shrubs and flowers—20-60 cu. yds. per acre (or 1¼ to 3¾ cu. ft. per 100 sq. ft. of soil).

Fortifying Digested Sludge

Fortifying sludge with chemicals will increase its total food constituents and hence its value. Such sludge should be applied in smaller amounts, depending on the type of crop and the local soil conditions. We understand from commercial fertilizer distributors that a 3-8-7 formula will be available for home gardeners this year instead of a 5-8-7 formula ordinarily recommended for general use. This means a cut of 2 per cent in the total nitrogen. If the new formula is mixed in equal proportions with sludge (on a dry basis), it will result in a 2.4-4.8-3.6 mixture. Or the following formula can be used, this being suitable for general use on almost any crop or soil:

Digested sludge (dry basis)	400 lbs.*
Ammonium sulphate†	60 lbs.
Acid phosphate (20%)	100 lbs.
Muriate of potash	40 lbs.

*400 lbs. of bone dry sludge amounts to about ½ ton of sludge cake as removed from the average sand drying bed or 1,300 lbs. of cake as removed from the average vacuum filter. Roughly ¾ of a cu. yd. or about 20 cu. ft. Other formulae may be used for special cases or a particular soil.

†May not be available this year because of war conditions.

Use of Sludge as Fertilizer

Some of the uses of sludge have already been pointed out. It is particularly adapted to lawns. Sludge deepens the green color of grass and stimulates a luxurious growth. Its benefits seem noticeable for several years. It should be applied in the amounts given above late in March and again early in September.

The home owner may well use it for the flower garden. Here it provides a much needed humus for the hot summer months as well as supplying a moderate but long-yielding amount of nitrogen.

Its use is also indicated for trees and shrubs. Trees fertilized with sludge frequently have a healthier foliage, both in amount and color, and retain their leaves for a longer time in the fall than nearby unfertilized trees.

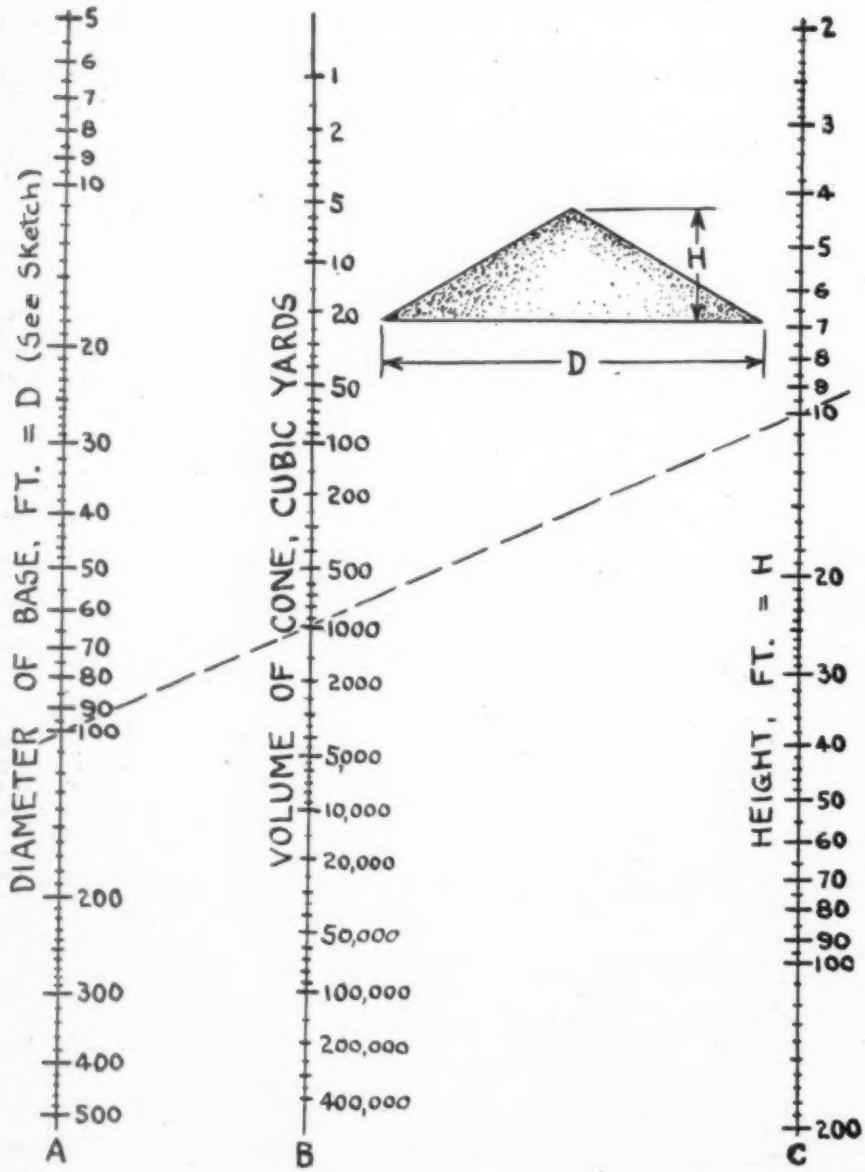
In the vegetable garden its uses have already been suggested. It has been found to be particularly beneficial for corn, potatoes, beans, spinach, asparagus, and all vine crops. With the scarcity of animal manure, the victory gardener might well turn to sludge for his humus needs, bearing in mind the safeguards discussed above. The cost of manure in his community may be used as a rough index of the value of local sludge. A charge of from 25 cents to $2 per cubic yard for unground sludge is frequently made at sewage plants. Sludge may be transported in truck bodies or bagged for hauling in smaller amounts by private car.

Why Digested Sludge Has Not Been More Widely Used as a Soil Conditioner

What are some of the reasons why digested sludge has not been used more extensively as a soil conditioner? Undoubtedly an aesthetic dislike to its use because of its origin and source, and the fear of producing offensive odors, are paramount in the minds of many laymen and agriculturists. Since properly digested and dried sludge, and heat-dried and ground raw activated sludge have been established as safe hygienically for application to the soil, there appears little room for argument from the health standpoint against use of such sludges. With regard to odor, many of the more common animal manures, including cow, pig and poultry wastes, have as much or more odor than sludge, especially if applied before they are thoroughly rotted or composted.

Another reason why sludge is not used is the lack of promotion of its use. In some cases this is no fault of the plant operating personnel, but is caused by a lack of time. The primary job of sewage treatment plant personnel is the protection of the public health and the prevention of nuisance from raw sewage, and not the manufacture or sale of fertilizer. Sludge disposal as fertilizer, when it involves salesmanship, storage facilities, grinding equipment, and in some cases bagging facilities, delivery and bookkeeping, is beyond the scope of many of the smaller treatment plants.

An objection to the use of sludge as a fertilizer is the lumpy or chunky physical form of much sludge cake, which makes it unsatisfactory for lawns, shrubs, and flower beds. Heat-drying or air drying and grinding produces a product much more suitable for general use.



CONTENTS OF CONICAL PILES*

Frequently it becomes desirable or necessary to estimate yardage in a pile of dirt, sand, stone, gravel, coal, etc.

Without any figuring whatever the accompanying chart quickly gives the number of cubic yards in any conical pile.

For example, how many cubic yards in a conical pile whose based diameter is 100 ft. and whose height is 10 ft.?

The dotted line drawn across the chart shows how it is done. Run the line through the 100 ft. diameter, column A, and the 10 ft. height, Column C, and the intersection with column B gives the answer as a little less than 1000 cubic yards.

The range of the chart takes care of all diameters from 5 to 500 ft. and all heights from 2 to 200 ft. However, in the event that diameters or heights should be greater or less the same chart is still applicable. Thus if the diameter should be 1000 ft. instead of 100 ft. and if the height should be 100 ft. instead of 10 ft., the same dotted line would solve the problem excepting that the answer would be 1,000,000 cubic yards instead of 1000 cubic yards. In that case the rule is this: For every cipher added to column A, add two ciphers to the answer in column B, and for every cipher added to column C, add one cipher to the answer in column B. This means that when the problem is 1000 ft. diameter and 100 ft. height, three ciphers must be added to the result in column B.

*Contributed by W. F. Schaphorst, M.E.

ROYER FOUNDRY & MACHINE COMPANY

170 Pringle St., Kingston, Pa.

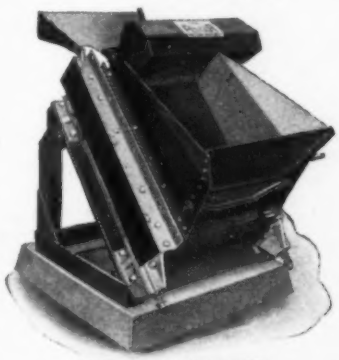
Manufacturers of the

ROYER SLUDGE DISINTEGRATOR

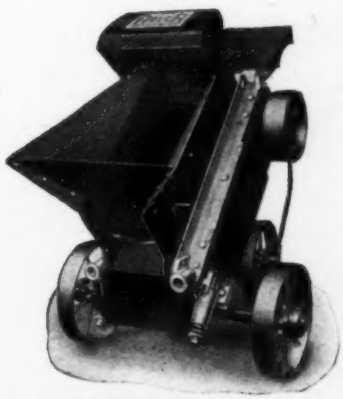
Royer "Jr." (Gasoline Engine)

Royer "Jr." (Electric Motor)

Model "NSH"



Model "NSD-S"



Model "NSM-2"

Profits from Your Sludge

The practice of burning or burying sewage sludge was wasteful enough in peace-time, and is much more so today. America must have more fertilizer if we are to produce the greatly increased volume of food required to feed millions of people overseas as well as our own population. Production curtailment of imported and domestic fertilizing materials makes it essential that every available source be utilized to the utmost. Sewage sludge has, when properly prepared, the properties of a most productive fertilizer, which definitely increases food crops.

Hundreds of sewage disposal plants are selling fertilizer at a substantial profit or are utilizing it at parks, municipal golf courses and institutional grounds, and have eliminated the cost of sludge disposal by means of the Royer Sludge Disintegrator. You, too, can profit in this manner.

Sludge from the drying beds is shoveled into the hopper of this rugged, inexpensive machine, which thoroughly shreds, mixes, aerates and further dries it. The Royer discharges an excellent fertilizer onto pile or truck, suitable for truck farms, under-glass growing and Victory gardens. The Royer is also used in city parks for mixing lawn top dressing.

The Royer soon pays for itself at a sewage disposal plant. It is available in twelve stationary and portable models; in sizes for every plant; electric, gasoline engine or belt-to-tractor driven. Over 5,700 Royers are in use the world over.

Write for new "Sewage Sludge Utilization Datalog."

THE ROYER

ROYER FOUNDRY & MACHINE CO. KINGSTON, PA.

RATIO OF SLUDGE DENSITY TO VOLUME

An Important Consideration in Operating

By GORDON J. WIEST, Chief Chemist
Chester Sewage Works, Chester, Pa.

THE variation in sludge volumes with solids content changes determines the most effective use of sludge handling and other treatment facilities in a sewage treatment works.

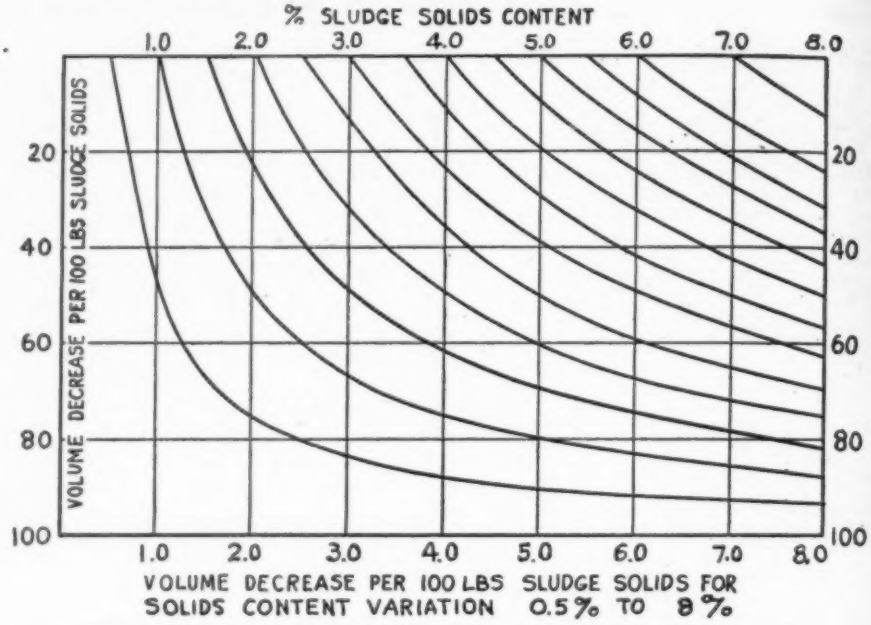
In this all important consideration it is, of course, the amount of liquid mixed with the sludge solids that determines the volume to be handled, and since the volume varies so markedly with the per cent of solid matter contained, this fact has important significance to the sewage works operator and engineer. The effect extends to the operation of digestion tanks, concentration tanks, aeration units, pumping and piping facilities, sludge storage, and other treatment units.

It becomes apparent that all the efforts of a sewage works operator to secure a more concentrated sludge contribute sizeable dividends to plant efficiency and operating expense, when one considers that a rise in moisture content by a mere 2.5% means 100% more liquid volume to be handled per one hundred pounds of sludge solids, when the water content rises from 95% to 97.5%. By the same token a sludge of 99.5% water, as against 97%, has a volume 500% greater. When using, as a base, the same quantity of solids to be handled, a digesting sludge of 95% moisture occupies just one half the space of a sludge of 97.5% moisture. The significance of this matter is that the digestion period of the sludge may be doubled by what may look to be an insignificant decrease of only 2.5% water content. If a sludge with 95% moisture passes through a digester in a theoretical (calculated) time of thirty days, and the sludge becomes thinned to 97.5% moisture, two things happen to give a serious change in digester operation. These are:

(1) The solids pass through the digester in one-half of the theoretical time (actually more nearly one-quarter of the time, due to disturbance of solids, dilution, and intermixing of new and old solids).

(2) It will require approximately 100% more heat input to maintain a given temperature in the digestion tank because there is twice the volume of liquid to be raised to the desired temperature.

The marked changes due to a combination of these two effects are not hinted in the mere 2.5% more moisture content of the sludge which appears in the operating records. On the other hand if we recorded sludge concentration in terms of pounds of solids per 1000 gals., or the reverse, rather than percent solids, the volume relationship would become very much more evident to us in following operating records.



Curves Revealing Marked Effect of Sludge Volume Reduction Through Concentration.

Note that increasing solids content from 0.5% to 3.5% reduces volume to 1/6 original. This in the Activated Sludge Process is of great significance.

The relation of moisture content to the volume of sludge handled magnifies itself many times in activated sludge practice. For example, the difference between a sludge of 99.5% and 97% water is represented by a volume reduction of the magnitude of 6 volumes reduced to 1 and is of very real consequence and importance. The meaning of sludge volume decrease to an operator of an activated sludge plant may be easily evaluated upon a careful examination of operating data and any permissible measure of securing sludge concentration has high justification in improved operation and economy.

The accompanying graph shows the relation of sludge volume to solids content variations more fully than any number of words or further examples.

Decimal Equivalents

of 8ths, 16ths, 32ds, and 64ths of an Inch

8ths		32ds		64ths	
1/8 = .125	9/16 = .5625	1/32 = .03125	17/32 = .53125	1/64 = .015625	33/64 = .515625
1/4 = .250	11/16 = .6875	3/32 = .09375	19/32 = .59375	3/64 = .046875	35/64 = .546875
3/8 = .375	13/16 = .8125	5/32 = .15625	21/32 = .65625	5/64 = .078125	37/64 = .578125
1/2 = .500	15/16 = .9375	7/32 = .21875	23/32 = .71875	7/64 = .109375	39/64 = .609375
5/8 = .625		9/32 = .28125	25/32 = .78125	9/64 = .140625	41/64 = .640625
3/4 = .750		11/32 = .34375	27/32 = .84375	11/64 = .171875	43/64 = .671875
7/8 = .875		13/32 = .40625	29/32 = .90625	13/64 = .203125	45/64 = .703125
		15/32 = .46875	31/32 = .96875	15/64 = .234375	47/64 = .734375
16ths				17/64 = .265625	49/64 = .765625
1/16 = .0625				19/64 = .296875	51/64 = .796875
3/16 = .1875				21/64 = .328125	53/64 = .828125
5/16 = .3125				23/64 = .359375	55/64 = .859375
7/16 = .4375				25/64 = .390625	57/64 = .890625
				27/64 = .421875	59/64 = .921875
				29/64 = .453125	61/64 = .953125
				31/64 = .484375	63/64 = .984375

SLUDGE INCINERATION

A Review of Modern Developments and the Status of the Practice

By E. T. KILLAM

Consulting Engr., New York, N. Y.

Developments in treatment plant equipment during recent years have demonstrated the feasibility of treating sewage essentially without nuisance—in, or adjacent to, closely built up areas. The economic advantages of elimination of long interceptors, and the prevention of deterioration of sewage quality prior to treatment by reducing detention time in interceptors, frequently establishes the desirability of constructing plants relatively close to centers of population instead of at remote locations, essential with some of the older types of plants. The increased importance of satisfactory sludge handling under such conditions has, among other factors, stimulated interest in sludge destruction by burning.

Methods of Sludge Drying and Incineration

Methods of drying and incineration of sewage sludge may be summarized as follows:

(*A*) *Drying* (*For Fertilizer*)
- (1) Without Preliminary Dewatering
  - (a) By Spray Dryer, such as at Plainfield, N. J.
- (2) With Preliminary Dewatering on Sand Drying Beds
  - (a) By Rotary Dryers at Grand Rapids, Mich., and Dayton, Ohio
- (3) With Preliminary Dewatering on Vacuum Filters
  - (a) By Rotary Dryers at Milwaukee, Wis.; Pasadena, Calif.; Houston, Texas

(*B*) *Complete Incineration*
- (1) After Dewatering on Sand Beds
  - (a) By Incineration in garbage-rubbish type incinerator of conventional design, contemplated or tried at a few plants with no known case of routine operation
- (2) After Dewatering on Vacuum Filters
  - (a) By Multiple Hearth Type Units for drying and incineration in one-step
  - (b) By Flash Dryer and Pulverized Fuel Type Incinerators, including drying followed by optional incineration

(*C*) *Complete Incineration of Screenings*
- (1) After Partial Dewatering in Roll Press
  - (a) In Hand Stoked Modified Garbage and Rubbish Type Incinerators, at Los Angeles "Hyperion" plant since 1934, and at Westchester County Sanitary District Plants since 1930
- (2) After Partial Dewatering in Centrifugal Machines
  - (a) At Milwaukee in hand stoked modified garbage and rubbish type incinerators
  - (b) At Milwaukee and Niagara Falls in multiple hearth type mechanically stoked—since 1937.

In addition to the foregoing applications of drying and incineration of sewage sludge and screenings, equipment now available offers a variety of special combinations deserving consideration in certain cases, and depending upon local conditions. Of particular interest are the possibilities in the combined disposal by incineration of garbage, rubbish, and sewage solids.

It is well recognized that the properly designed and well operated garbage and rubbish incinerator of today, will, under normal conditions, produce a substantial volume of excess heat.

There are notable examples of effective utilization of waste heat from garbage incineration in producing steam and power. The production of power, however, creates certain demands which must be considered in design and operation, and economical power production will for some time be limited to plants of substantial size.

An alternate use of such excess heat from garbage incineration (namely, as a means to drive off sufficient moisture from the sewage solids to make the sludge combustible without purchased auxiliary fuel) affords an interesting application of combined disposal.

Incineration and drying of sewage solids has doubtless been retarded due to the recognized item of operating cost, for driving off the moisture in the upper range of moisture content. If heat which would otherwise go up the incinerator stack may be utilized for this purpose, a consequent substantial reduction in operating cost is effected. This saving, combined with other obvious advantages, in many locations, of constructing the sewage disposal and garbage incineration plants at a common site, should make combined wastes incineration worthy of consideration in numerous instances, and the scope of applicability of incineration of sludge will, thereby, be substantially widened.

Inasmuch as the recent installations have been of the multiple hearth type, or the flash dryer and incineration type, these methods will be further discussed in brief.

Multiple Hearth Type Incineration

In 1934 the multiple hearth type incinerator, developed in the mining industry for roasting copper ore, was first applied to the incineration of sewage sludge at Dearborn, Michigan. In this, as in later installations, sludge is partially dewatered on vacuum filters prior to incineration.

The multiple hearth incinerator consists of a refractory lined circular steel jacketed unit, with as many hearths as may be indicated for the specific installation. Rotating plows on each hearth, driven by a vertical hollow air-cooled central shaft, constantly agitate and plow the material during drying and burning. The material drops through staggered openings in each hearth, to the next hearth below, being finally discharged from the bottom hearth in the form of an inert ash.

Multiple hearth installations normally include a blower for producing a supply of cooling air for the hollow shaft and revolving arms, a motor for driving the rabble arms, a rotating motor driven feeder, oil burner installation, and temperature control equipment.

In several cases preheaters have been included in the layout. The economic justification for a preheater, by means of which waste gases are utilized to heat the air supply to approximately 900 degrees F., depends upon the plant size, contemplated daily duration of operating period, and character and moisture of sludge to be burned.

The planned range of temperature at the furnace exit is approximately 1100 to 1300 degrees F. under normal optimum operating conditions.

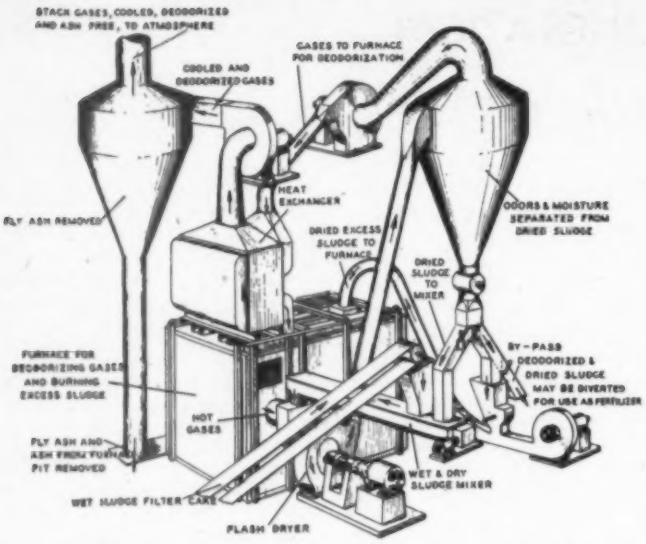
Beginning with the notable pioneering installation at Dearborn, Michigan, in 1934, numerous installations of the multiple hearth type incinerator have been undertaken. Recent reports indicate that equipment of this type has been, or is being installed, in 21 or more plants at this writing.

Installations at various plants to date vary in size from a single 9 ft. 3 in. diameter unit of four hearths, to the largest installation at Detroit, where four 22 ft. 3 in. diameter, 12-hearth units have been installed. It thus appears that America's largest Multiple Hearth Furnace installation is approximately seventy times the size of the smallest installation.

The original Dearborn incinerator handles mixed raw chemical and digested Imhoff sludge, the quality of which is indicated by the fact that the long term average volatile content of the cake fed to the incinerator was 46.6 per cent.

Subsequent installations have been in plants which will produce sludge of widely varying characteristics, including the following:
- (a) Raw Primary
- (b) Raw Chemical
- (c) Digested Primary
- (d) Raw Activated
- (e) Digested Activated

Several units have been purchased for incineration of fine screenings and 5 units have been installed with the expressed intention of handling ground garbage along with the sludge.


STACK GASES, COOLED, DEODORIZED AND ASH FREE, TO ATMOSPHERE
GASES TO FURNACE FOR DEODORIZATION
COOLED AND DEODORIZED GASES
HEAT EXCHANGER
FLY ASH REMOVED
DRIED EXCESS SLUDGE TO FURNACE
ODORS & MOISTURE SEPARATED FROM DRIED SLUDGE
DRIED SLUDGE TO MIXER
FURNACE FOR DEODORIZING GASES AND BURNING EXCESS SLUDGE
BY-PASS DEODORIZED & DRIED SLUDGE MAY BE DIVERTED FOR USE AS FERTILIZER
HOT GASES
FLY ASH AND ASH FROM FURNACE PIT REMOVED
WET & DRY SLUDGE MIXER
WET SLUDGE FILTER CAKE
FLASH DRYER

The C. E. Raymond System of Flash Drying and Incineration. (This System Makes Permissible Complete Sludge Incineration or a Partial Diversion for Use as Fertilizer. Another Illustration Shows the Cyclone End of the Raymond System in Service.)

Flash Drying and Incineration

Flash drying and incineration of sewage sludge was first undertaken on a large scale at the West Side Plant of The Chicago Sanitary District in 1933.

This type of equipment involves incineration in two stages—or in other words the drying of the solids to approximately 10 per cent moisture, followed by incineration of the dried material.

The filter cake, with a normal moisture of 75 to 85 per cent, is mechanically mixed with sufficient dried material to develop proper consistency for drying in the flash dryer. Hot gases and this mixture drop into the flash dryer, are violently agitated, and the dried material and vapors are discharged into a cyclone collector. The dried material—approximately 10 per cent moisture—is mechanically divided, a portion being returned to the mixer for blending with the wet filter cake. The balance, or excess, is sent to storage for fertilizer or to a pulverized fuel type of incinerator for destruction, as the case demands. The vent vapors are likewise discharged to the incinerator.

The average design temperature in the dryer is 1100 to 1300 deg. F., and the temperature of the vent vapors varies from approximately 200 to 300 degrees.

The initial installation—at Chicago's West Side Plant, was designed to dry and incinerate raw activated sludge filter cake at 80 to 85 per cent moisture. The rated capacity is 2,000 pounds net dry solids per hour or 8,000 pounds of water evaporation per hour.

Basing the design upon the performance of this unit, equipment was installed at the Calumet Plant of the Chicago Sanitary District and placed in operation in 1935. Three units—each with a capacity of 6,000 pounds net dry solids per hour, or 24,000 pounds of water evaporation per hour, were included. The sludge handled consisted of raw activated filter cake—with small amounts of grit and heavy primary solids from 20 minute detention primary tanks.

In November, 1937, this same type of equipment was placed in service at Neenah-Menasha, Wisconsin, with a capacity of 0.75 tons dry solids per hour, or 3,500 pounds of water evaporation per hour. The sludge at this plant will at times be digested—primary sludge, and at other times will be chemical sludge. A large proportion of paper mill wastes—with high clay content, has at times developed sludge as low as 35 per cent in volatile content.

Similar equipment is now being installed at Buffalo, New York, for incineration of partially digested primary sludge. This plant includes three units each, with a capacity of 5,000 pounds per hour evaporation.

The largest installation of flash drying equipment is in Chicago's notable South West Activated Sludge Plant, where four units—each served by two drying units, with the latter having an evaporation capacity of 20,000 pounds each per hour, are being installed. In this installation power will be generated from combustion of the pulverant dried sludge, with the assistance of auxiliary powdered coal. In this single plant with a total evaporation capacity of 40 tons per hour, combustion engineering has attained a real goal in sewerage practice in America.

The first installation under contract locally, is at Tenafly, N. J., where a small single unit of the drying apparatus, with an evaporation capacity of approximately 0.35 tons per hour, is to be installed, for drying raw activated sludge filter cake and fine screenings, preparatory to the burning of the dried material with garbage and rubbish in open hearth incinerator of conventional design.

Summary

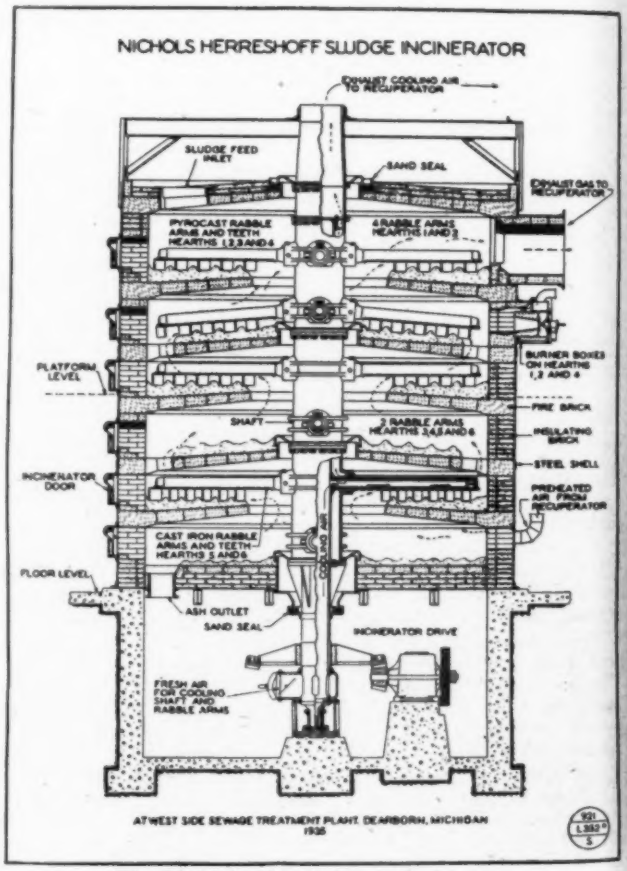
In summary, sludge disposal by drying or incineration has constituted one of the most active phases of development, in the past few years, in the field of sewage treatment.

While operating data and operating costs for a variety of installations will soon be available, it can be safely stated that careful consideration of the local conditions in each municipality will be necessary in order to approach the most economical solution of the problem.

The variables affecting alternate methods of sludge disposal vary no less than the wide range of requirements for degree of sewage treatment. In this way, it would appear that a careful analysis of the problem prior to final selection of the method of sludge disposal, will necessitate thorough consideration of the variables involved.

The characteristics of the sludge and moisture and combustibles content vary widely, depending upon the type of treatment from which the sludge originates. The volatile content of various sludges may vary to as wide a range as from 30 per cent of the total dry solids, to 80 per cent, or even higher. While a heat value of 10,000 B.t.u. per pound of dry volatile matter has frequently been used in computation, additional experience indicates wide variations in B.t.u. content per pound of combustibles.

The demonstrated performance in sludge incineration during the past few years, however, has placed this much needed facility in an important position as a method of sludge disposal. The above variables mentioned will not, it is believed, be of sufficient importance to jeopardize the success of the method, but will affect merely the economic advantages of one method or type of incinerator over another, where incineration is indicated as the preferred method.


NICHOLS HERRESHOFF SLUDGE INCINERATOR
EXHAUST COOLING AIR TO RECUPERATOR
SLUDGE FEED INLET
SAND SEAL
EXHAUST GAS TO RECUPERATOR
PYROCAST RABBLE ARMS AND TEETH HEARTHS 1,2,3 AND 4
4 RABBLE ARMS HEARTHS 1 AND 2
BURNER BOXES ON HEARTHS 1, 2 AND 4
PLATFORM LEVEL
FIRE BRICK
SHAFT
2 RABBLE ARMS HEARTHS 3,4,5 AND 6
INSULATING BRICK
STEEL SHELL
INCINERATOR DOOR
PREHEATED AIR FROM RECUPERATOR
CAST IRON RABBLE ARMS AND TEETH HEARTHS 5 AND 6
FLOOR LEVEL
ASH OUTLET
SAND SEAL
INCINERATOR DRIVE
FRESH AIR FOR COOLING SHAFT AND RABBLE ARMS
AT WEST SIDE SEWAGE TREATMENT PLANT, DEARBORN, MICHIGAN 1935

The Multiple Hearth Dryer-Incinerator

EQUIPPING THE SEWAGE PLANT LABORATORY

With Particular Reference to the Smaller Plants

By NORMAN C. WITTWER, Consulting Engineer
Trenton, New Jersey

SEVERAL excellent articles have been published on the arrangement and functions of large sewage treatment plant laboratories, but very little definite information is available pertaining to a laboratory suitable for sewage plants of from 0.5 m.g.d. to 10.0 m.g.d. capacity. It is the purpose of this article to describe in detail the furnishing, equipping and arranging of a compact laboratory suitable for necessary routine control and statistical determinations.

No discussion will be made of the methods of sewage analysis, or of laboratory technique, as these subjects are thoroughly covered in such publications as the "Standard Methods of Water Analysis," published by the American Public Health Association, and "Analysis of Water and Sewage," by Theroux, Eldridge, and Mallman, published by the McGraw Hill Book Co., New York City.

The laboratory herein considered is complete in every respect for the average sewage treatment plant, although special conditions or plant processes may require some additional facilities. The analyses which may be performed in the laboratory to be described are:

Solids—Suspended, Dissolved and Volatile.
Sludge—Moisture, Solids, Ash.
Sludge Index (Activated Sludge).
pH—Sewage and Sludge.
Dissolved Oxygen (D.O.).
Bio-chemical Oxygen Demand (B.O.D.).
Oxygen Consumed.
Chlorine Demand.
Residual Chlorine.
Relative Stability (although not recommended).

Special apparatus has not been provided for sewage gas analysis, nitrogen determinations, or for bacteriological work. Such determinations are not ordinarily a part of routine laboratory work, although many of the larger plants undertake more extensive analyses.

Laboratory Furniture

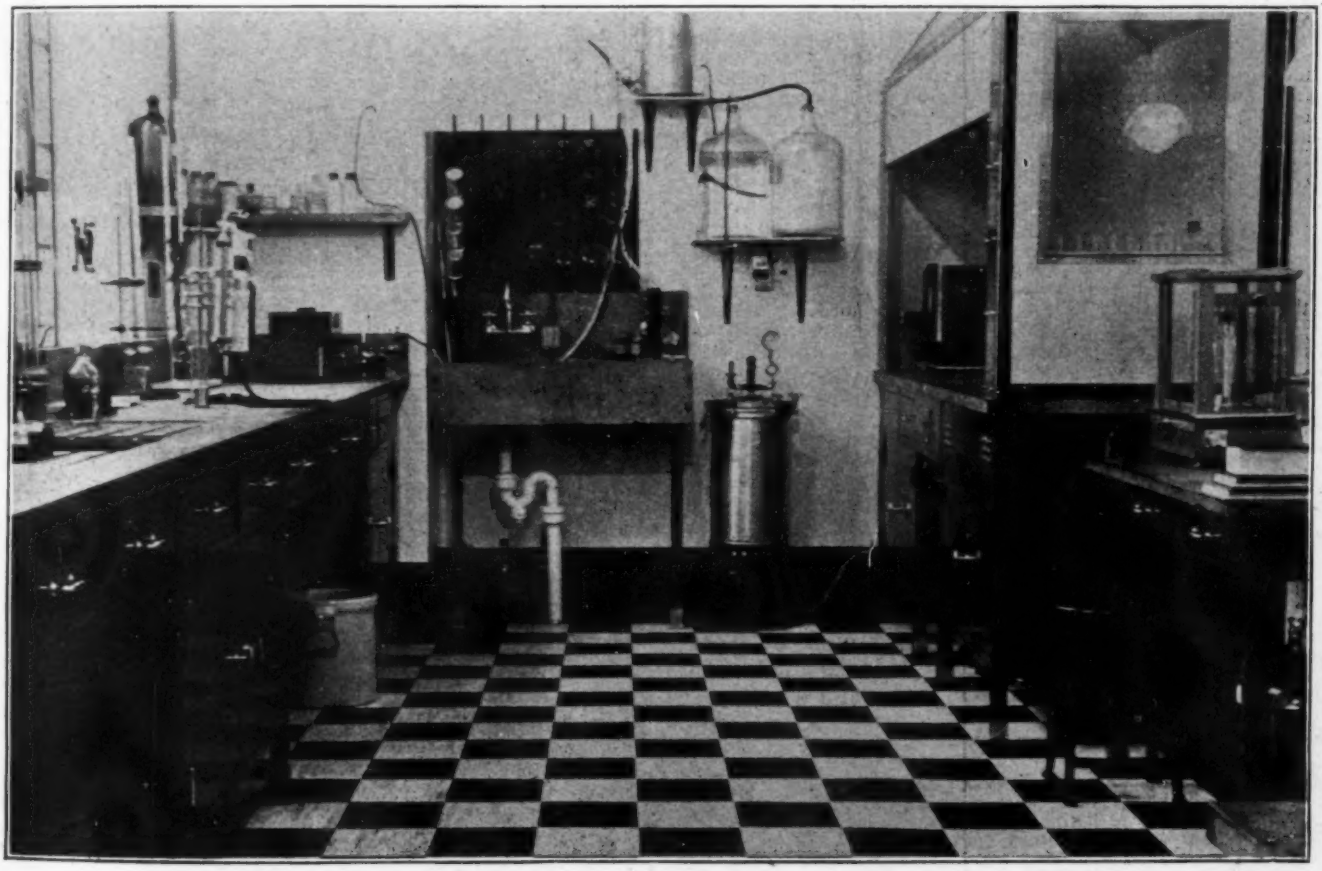
The scope and arrangement of the laboratory is of prime importance. Many plant laboratories have been laid out and constructed with but scanty appreciation of the facilities required. Since cost is in most cases of great importance, it is the aim of the author to present a laboratory which is compact, entirely complete for the purpose intended, and yet as economical as is possible without sacrificing needed facilities or necessary quality of equipment and apparatus.

Such a laboratory is complete in a room 12 feet wide by 15 feet long. It is based on the experience gained in the author's own laboratory, and in laying out laboratories for other plants.

Certain fundamentals are essential, and must be provided if the worker is to be expected to properly perform his duties. They are as follows:

1. Adequate work table space.
2. A suitable sink with goose-neck faucet with at least 15 inches clearance above sink bottom, and a peg board for draining and drying glassware.
3. A dependable supply of distilled water.
4. An adequate number of gas, air, hot water and cold water hose cocks, and other necessary connections.
5. Fume hood with forced ventilation.
6. Balance table.
7. Electric refrigerator for storing and preserving samples.
8. B.O.D. Incubator.
9. Drying oven.

*When this article was written the author was Supervising Engineer for the Rahway Valley Joint Meeting, the authority which operates the sewer systems and a central treatment works for Rahway, N. J., and eight other participating municipalities.—Ed.



One End of the Laboratory—Rahway Valley Plant

10. Steam bath.
11. Muffle furnace (for ashing solids).
12. Arrangement for filtration through Gooch crucibles.
13. Cabinets for reagents and solutions.
14. Shelving for small bottles, etc.
15. Cupboard and storage space for glassware, miscellaneous equipment and supplies.
16. Adequate light, a very important consideration.

Furniture Specifications

Laboratory workers differ in their preferences for wood or steel furniture, and for stone or hard-wood work-table tops. This is not so important, as both have proven satisfactory. A set of detailed specifications are given below, which are extracted from the contract specifications for a sewage treatment plant laboratory now under construction. These specifications are for steel equipment, but can be readily adapted to wood furniture if so desired.

1. *Make of Furniture*—The furniture installed under this contract shall be from a manufacturer who has made at least five satisfactory installations of steel laboratory furniture of materials such as are herein specified, and which installations have been in satisfactory service for two or more years.

2. *Steel*—Sheet steel shall be of a copper-bearing steel alloy, containing not less than one-quarter of one per cent copper, and shall be hot-lead-coated on both sides, on sheared edges and spot welds so that the steel shall be fully protected against corrosion. All sheets shall be prime grade, stretcher-levelled, free from uncoated spots, deep scratches or other injurious defects. All drawer heads and cupboard doors shall be of No. 12 gauge thickness; drawers and small shelves shall be of No. 20 gauge, all other sheet steel work shall be of No. 18 gauge. Gauges specified above and elsewhere herein are U. S. gauge.

3. *Cabinets and Supports*—All cabinet work shall be sanitary, vermin-proof flush type, without recessed or projecting panels. It shall be designed and constructed for laboratory use, with pipe ducts, racks, removable backs, shelves and adjustable legs for levelling.

Sides, backs and bottoms of cabinets shall be of No. 18 gauge. Sides of cabinets shall be of one piece, formed into a U-shaped corner post at the front, the inner sides of which shall be formed into a door strike. The upper and lower edges of the cabinet sides and back and front rail shall be formed into a channel member ,reinforced with a continuous angle frame of 1¼ x 1¼ x ⅛ inch copper steel, mitred and welded at the corner, to which the legs shall be welded. Backs and shelves shall be removable from the inside, so that piping may be installed or removed without dismantling any part of the table. Backs shall fit into clips at the bottom. At the top, the back shall be flanged in a 7/16 inch flange or back panel, and shall be held in place with two screws at the ends.

Legs of cabinets shall be of No. 14 gauge, 1½ inch square seamless tubing, 8 inches high; and shall be acetylene-welded to the angle iron frame of each individual cabinet at the bottom of the cabinet. After the legs are welded to the frame, the frames with th eattached legs shall be dipped into a vat of hot lead so that all surfaces and welds shall be fully coated and protected. Each leg shall be fitted with a drive fitting, non-ferrous die-cast, micro-levelling device, with six prongs and clip wells. The shoulder of the levelling devices shall rest on the bottom of the square tube legs, and shall then be permanently attached to the leg by forcing the metal leg into the depression on the device. The shoulder shall extend ¼ inch below the bottom of the leg. Each levelling device shall be fitted with a 2½-inch long hexagonal bolt, cadmium plated and furnished with stainless steel floor plates. The levelling device shall be covered with a duraluminum shoe cover plate as hereinbefore specified.

Cupboard doors shall be of No. 12 gauge, hung on a pair of No. 10 gauge, lead dipped, offset, five knuckle hinges, with round head brass fixed pins and with concealed flaps; one flap shall be blank and welded to the door, the other shall be fastened to the cabinet post with three bolts. Doors shall be provided with a lead-plated three-way locking device, locking both doors at the top, bottom and center at one time by a not less than 2⅜ x 1⅜ inch oval shaped, solid cast aluminum alloy knob with a ⅜ inch square brass stem cast and pinned into the knob engaging a stamped locking cam of No. 12 gauge and two ⅝ x ⅛ inch sliding bolts.

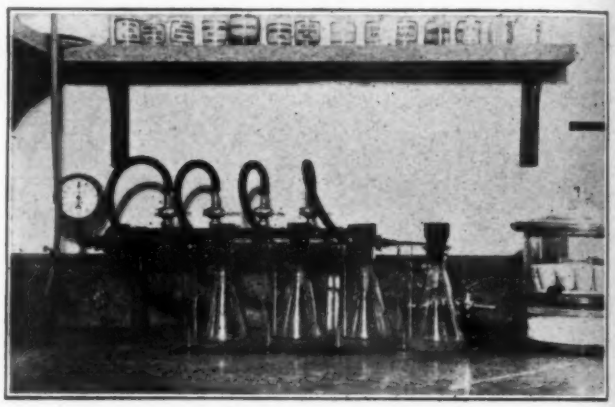
Drawers shall be of No. 20 gauge, the upper edge of the sides and back of which shall be reinforced and formed into a U-shaped head. The front of the drawers shall be of No. 12 gauge. Each drawer shall operate on four ⅞-inch diameter cadmium-plated ball-bearing rollers, operating on extension channel runners. Runners shall be formed of No 14 gauge, and shall support the drawers rigidly when extended the full length. The drawer stop shall be fastened to the bottom of the drawer, and shall be concealed at all times. Drawer pulls shall be graceful in design and shall be of cast-aluminum alloy, fastened from the inside of the drawers with concealed aluminum alloy screws. The drawer pull shall not extend into drawer.

4. *Hardware*—All hardware, including the kick-plate shoes, shall be as described under laboratory cabinet construction and shall be of cast silicon-aluminum alloy, ground and polished to a satin finish. All screws shall also be of same aluminum alloy. All cocks and table fixtures shall be chromium plated.

5. *Finish*—All surfaces of steel work of laboratory equipment shall be first washed clean with benzine to remove all the oil and grit. Then one coat of neutral metallic filler shall be applied, baked and sanded; then one coat of rust preventing primer baked and sanded; finally two coats of dark green acid and alkali resisting enamel shall be applied.

6. *Main Work Table*—The main work table along the front wall of the laboratory (see plan) shall be 15 feet long (approximately) by 2 feet 6 inches wide by 37 inches high. The table top, the 6-inch high back, and the 4-inch cut-out at the window shall be of 1¼-inch soapstone. The sink in the table shall be 18 x 16 x 8 inches deep, and furnished with a Duriron waste fitting. The table shall be supported on complete combination drawer and cupboard units, with a 5-foot clear opening in front of the window. Drawers shall be provided for the full length of the table, with a dummy drawer in front of the sink to match the rest of the equipment. A 12-inch deep open shelf shall be provided across the clear opening in front of the window, with flange-up back and flange-down front. It shall be mounted at the bottom of the cupboard and toward the rear of the opening.

7. *Vacuum Manifold*—The table shall be equipped with one vacuum manifold fitted with four 3-way exhaust cocks and one 3-inch dial vacuum gauge. The manifold shall be mounted on suitable supports at the back of the table, and connected to the vacuum pump cock by means of flexible copper tubing with compression type couplings.



Vacuum Manifold and Filter Flasks
(Used in determination of total suspended and settleable solids. On right Gooch crucibles in desiccator.)

The 3-way cocks shall be fitted in the side of the manifold facing the front of the work table.

8. *Fittings for Main Work Table*—The sink shall be fitted with one combination hot and cold water goose neck drop faucet with hose end, the goose neck to be of such height as to clear 1000 ml. graduated cylinders. A cold water faucet shall also be provided, same to have a screw-type opening suitable for a Chapman aspirator. The table shall also be equipped with one pedestal type single air pressure cock, three pedestal type double gas cocks, and one pedestal type cold water cock.

9. *Vacuum Pump*—There shall be installed on the shelf of the cabinet space under the sink a suitable blower and vacuum pump for the operation of the vacuum manifold. These conditions are satisfied by a Cenco Rotary air cooled blower and vacuum pump driven by a ¼ horsepower motor mounted on a common base. (The electrical current characteristics must be given for the motor.) The motor shall be controlled by a push-button switch located at a convenient point on the wall above the main work table.

The vacuum side of the pump shall be connected with ¼-inch copper tubing, or extra heavy vacuum rubber tubing, to the exhaust manifold as indicated on the drawings. The pressure or exhaust side of the pump shall be connected to the air cock on the main work table with ¼-inch copper tubing.

10. *Work Table Shelving*—There shall be furnished and in-

stalled on the wall above the main work table, 1¼-inch thick by 6 inches wide soapstone reagent shelving mounted 22 inches above the top of the work table. The shelves shall extend along all walls of the work table, except for the window and peg board. The shelves shall be supported on suitable brackets, securely fastened and anchored to the building wall.

11. *Peg Board*—There shall be mounted on the wall at the right end of the work table a peg board of carbonized wood, 24 inches wide by 30 inches high.

12. *Fume Hood*—The fume hood shall be an open type fume hood 5 feet long by 2 feet 6 inches wide. The work table of the hood shall be supported by one 2½-foot combination drawer and cupboard unit. The hood shall be furnished with one 1000-watt pedestal-type duplex electric receptacle, two pedestal-type double gas cocks, one pedestal-type double water cock, and one four-hole gas-heated steam bath.

The steam bath shall be fully insulated, with a gas vent opening on the inside of the fume hood. The steam bath shall be constructed of No. 18 gauge stainless steel, and equipped with stainless steel concentric rings to cover the four 3¾-inch diameter openings. The bath shall be of the quick-steaming type, equipped with a suitable external water level regulator. A Hoke-Phoenix needle valve shall be used to control the water supply to bath, and the bath overflow shall be visible.

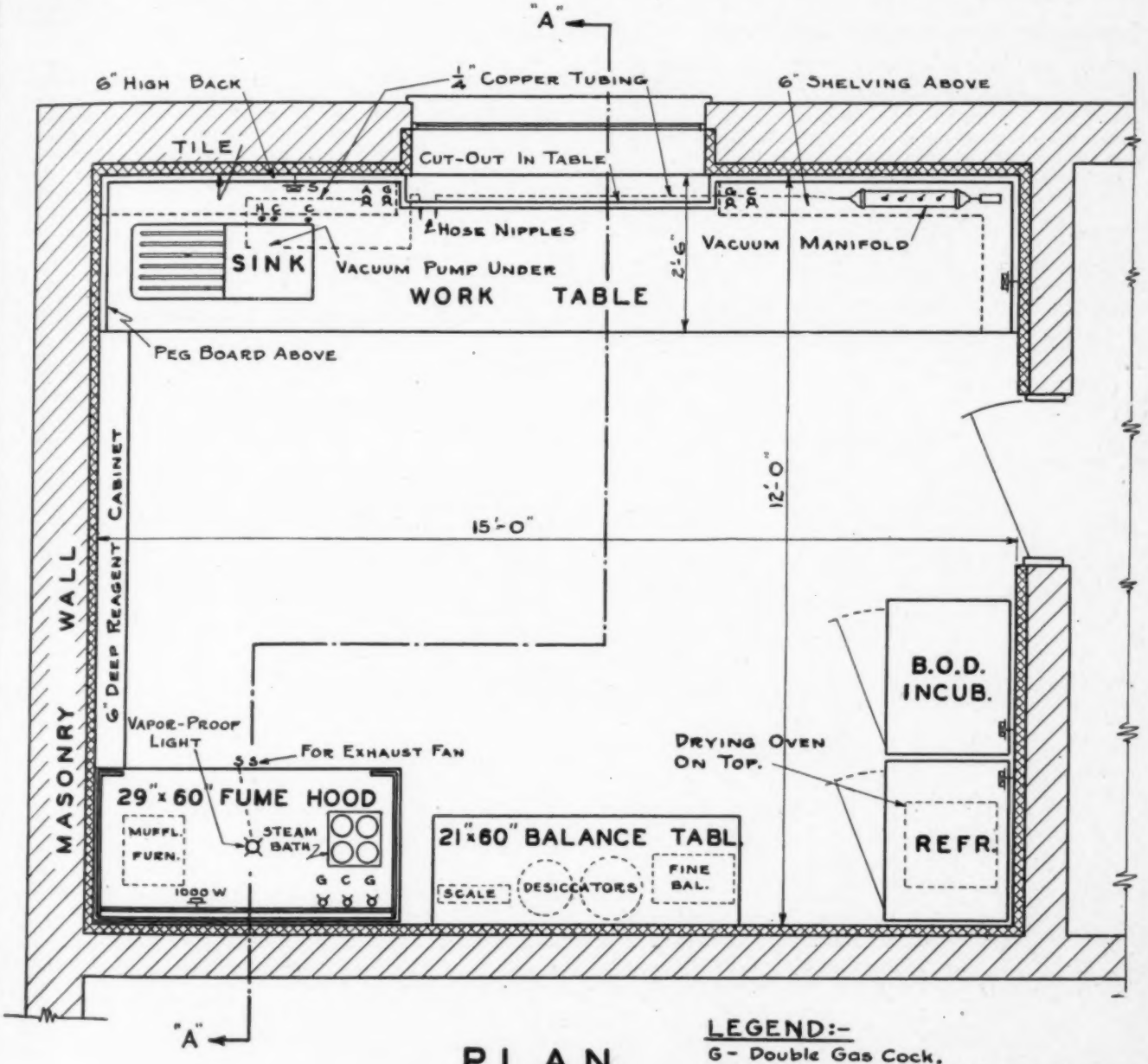
A suitable opening and connection shall be provided through to the top or rear of the hood for the installation of the exhaust fan.

13. *Hood Exhaust Fan*—A suitable exhaust fan shall be installed to exhaust the fume hood. The fan shall have a capacity to discharge not less than 225 cubic feet of free air per minute at free delivery.

The fan suction and discharge piping shall be of suitable acid fume resisting material, such as "Labite," "Transite," or vitrified tile. All joints shall be air tight, and the joints at the fan shall be made with high-grade, heavy rubber tubing to prevent vibration.

The exhaust piping shall terminate at the roof in a suitable size ceramic ventilating roof cap, properly flashed to the roof.

14. *Other Shelving*—There shall be furnished and installed the necessary shelving for the water still and the two 5-gallon distilled water carboys. If possible, the water still can be mounted on top of the reagent cabinet. The shelf for the 5-gallon car-



PLAN

LEGEND:-
G - Double Gas Cock.
C - Cold Water Faucet or Hose Cock.
H - Hot Water Faucet.
A - Air Cock.
S - Switch.
⊞ - Duplex Electric Outlet.

Suggested Layout of Sewage Works Laboratory

boys shall be of ⅜-inch Labite or Transite, 22 inches wide by 11 inches deep. It shall be mounted on heavy brackets of sufficient strength to carry the weight of the bottles, when full.

All brackets shall be securely fastened and anchored to the building wall.

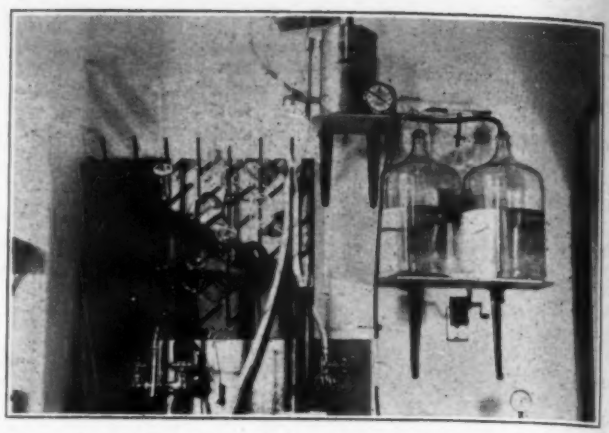
15. *Balance Table*—The balance table shall be 5 feet long by 1 foot 9 inches wide by 2 feet 7 inches high, and shall be constructed of 1⅝-inch diameter tubular steel with a cross bar at rear only to provide ample leg room. The floor flanges shall be such as to permit levelling of the table. A 4-inch high panel shall be provided under the table top into which shall be fitted two small drawers. The table top shall be of 1¼-inch selected soapstone.

16. *Reagent Cabinet*—There shall be furnished and erected an enameled steel reagent cabinet, 7 feet high and of suitable length, and 6 inches clear depth. The cabinet shall be constructed of No. 18 gauge steel with sliding steel doors glazed with No. 1 clear glass. The cabinet shall have five shelves, adjustable in height. The cabinet shall have three front legs, with provisions for bolting the cabinet securely to the wall.

The approximate cost of the laboratory furniture specified above is $1,250.00.

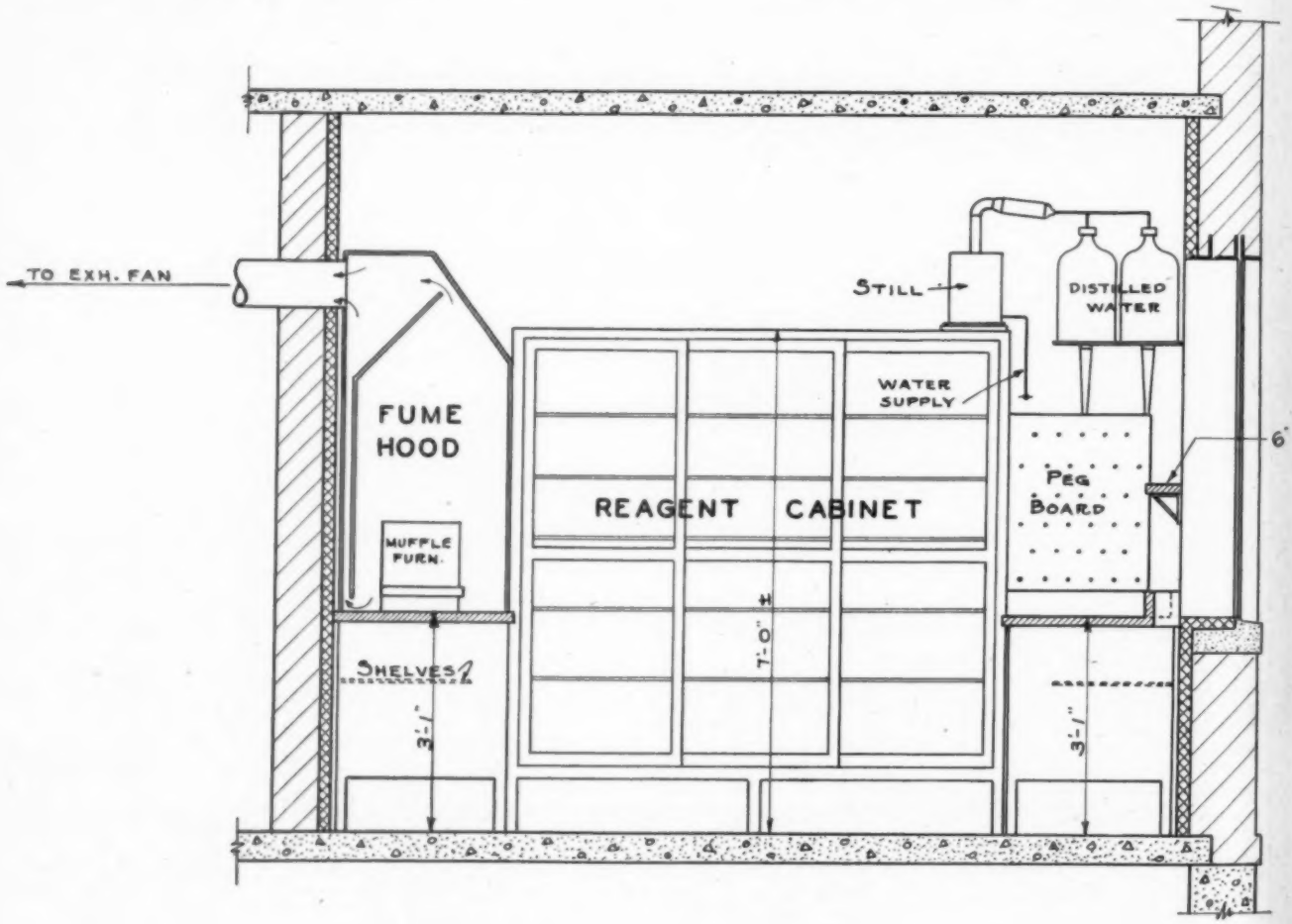
Permanent Apparatus and Equipment

In addition to the laboratory furniture, certain permanent apparatus will be required. The following list of this apparatus, as well as the "Minor Equipment Items" list and the "Reagents and Chemicals" list, has been carefully compiled, and checked against the equipment and experience of active plant laboratories. The "loading up" of the laboratory with unnecessary or little-used apparatus and equipment has been avoided. Enough equipment has been included to enable the chemist or operator to walk into the laboratory and commence work, without the all-too-customary wait for necessary items not originally included.



Peg-board Above Sink and Water Still on Right

In the preparation of such lists, cognizance is taken of the fact that certain manufactured items of equipment and apparatus have been found to be the most satisfactory for use in a sewage plant laboratory. It is also recognized that a general description of a particular item without the corresponding manufacturer's name or catalog number will not always enable a purchaser to obtain the article intended. Therefore, wherever deemed advisable, the manufacturer's name or dealer's catalogue number is



SECTION "A-A"

Suggested Layout of Laboratory—Section "A-A"

included in order to eliminate errors in the purchase of this equipment. Wherever possible, more than one manufacturer or dealer will be given.

The following abbreviations will be used throughout for several of the more prominent supply houses:

Arthur H. Thomas Company.....AHT
Eimer & Amend.....E&A
Central Scientific Co.....CSC

The catalog numbers thus given can be considered as standards of quality by which other competing houses can offer their merchandise.

Quantity	Description
1	B.O.D. Incubator 5 to 6 cu. ft. capacity (give current characteristics).
1	Analytical Balance with chain balance with channel notched beam, sensitivity to 1/20 mg. with magnetic damper, Christian Becker chainomatic No. 16, or E&A 16772/2.
1 set	Analytical Balance weight, 1 gm. to 100 gm. for chain balance.
1	Rubberized Balance Cover to fit balance.
1	Triple Beam Balance with agate bearings, including sliding weights and 500 gm. and 1000 gm. attachments. Equal to E&A 17026, 17026 A&B, or CSC 3600 & 3610.
1	Beckman pH Meter (Industrial Model).
1	Taylor-Enslow Slide Chlorimeter (where chlorine is being used).
1	Muffle Furnace, MU Type 62 Electric and Encased Rheostat (give current characteristics).
1	Electric Drying Oven, inside dimensions approximately 12″ x 12″ x 15″, with inside glass door. Elconap Type BO 15, or Weber Type B (give current characteristics).
1	½ gallon per hour Automatic Water Still, as made by either Barnstead or Stokes. May be for electricity or sewage gas. If for electricity give current characteristics.
1	International Clinical Electric Centrifuge with a 4-place combination head for two 15 ml. tubes and two 50 ml. tubes (give current characteristics).
4	15 ml. graduated resistance-glass conical-bottom centrifuge tubes.
4	50 ml. graduated resistance-glass centrifuge tubes with spouts, E&A 20065/4.
1	5 cu. ft. standard make electric refrigerator.

The approximate cost of the permanent apparatus listed above is $1,110.00.

It is possible to substitute cheaper equipment for some of the items specified, but such substitutions will inevitably result in frequent breakdowns and repairs, and unsatisfactory results. After all, the old axiom that "a workman is as good as his tools" holds good in a sewage plant laboratory as well as in a shop.

The centrifuge listed above is not absolutely necessary, but has been found to be very useful for controlling the drawing-off of supernatant liquor from digestion tanks, and in the operation of activated sludge plants.

Some chemists and plant operators still use colorimetric apparatus for pH determinations. However, a potentiometer, such as the Beckman pH Meter, specified above, is not only more accurate, particularly with sludges, but is also a great time saver to the busy worker.

Minor Equipment Items

This list includes all minor and renewable items such as glassware, brushes, burners, rubber tubing and stoppers, etc. Sufficient glassware is included to allow for reasonable washing intervals.

Quantity	Description
1	Actigel Analytical Balance Desiccator.
1	Fruhling & Shultz Desiccator, 10-inch, with cover and 10-inch Coors porcelain perforated plate.
1	Fruhling & Shultz Desiccator, 8-inch, with cover and 8-inch Coors porcelain perforated plate.
2	Balanced Watch Glasses, 3-inch (1 pair).
	Beakers, No. 1000 Pyrex Griffin low form with lip.
2	1000 ml. capacity
2	600 ml. capacity
4	400 ml. capacity
12	250 ml. capacity
6	100 ml. capacity
4	50 ml. capacity
	Bottles, Narrow Mouth, Flint Glass, round, for corks, AHT 2203, E&A 18652.
12	12 oz. capacity
12	8 oz. capacity
18	300 ml. B.O.D. Bottles, glass-stoppered with stoppers numbered consecutively from 1 to 18 to correspond with numbers on bottles. Numbering to be in black enamel figures. Bottles to be of Non-Sol-Vit glass, and not over 6½″ in height, including stoppers. (18 bottles will permit two determinations weekly on raw sewage and effluent.)
	Bottles, Narrow Mouth, glass stoppered tincture, with well ground flat stoppers, AHT 2220 or E&A 18680.
12	1000 ml. capacity
24	500 ml. capacity
12	250 ml. capacity
4	30 ml. Round Dropping Bottles with flat, grooved stoppers, AHT 2257 or E&A 18824.
4	30 ml. Square Dropping Bottles with rubber bulb stoppers and glass pipette E&A 18806.
1	Washing Bottle, 1 liter Pyrex complete with rubber stopper, glass tubes and rubber tubing joints.
4	5-gallon Narrow Mouth Glass Bottles, E&A 18650 (for distilled water).
6	2-gallon Narrow Mouth Glass Stoppered Bottles, AHT 2210-A (for B.O.D. dilution water and standard solutions).
4	1-gallon cider jugs (for compositing and storing samples).
1	Superior quality camel hair brush with wooden handle and ½-in. dia. tuft., AHT 2376 or E&A 19048 (for dusting scale pans).
6	Medium camel hair brushes, AHT 2378 or E&A 19042 (for cleaning watch glasses).
12	Test Tube Brushes with Puff Tuft end, tinned iron wire handle, 1½-inch diameter bristles, AHT 2389.
1	Cylinder Brush, bristle end, strong rattan handle, bristle 2 inches diameter by 4½ inches long, total length 25 inches, E&A 19072.
6	Pipette Brushes, length of bristle 7½ inches, AHT 2382, E&A 19074.
2	Burette Brushes, brass wire handles, tufted bristle end, AHT 2396.
4	Brushes, of black bristle, total length 12 inches, AHT 2363 or E&A 19092.
3	50 ml. Schellbach Burette with large straight glass stopcock, AHT 2436.
1	50 ml. Schellbach Burette with large three-way glass stopcock, AHT 2438.
2	Fisher Burette Supports, complete with clamps, base 7″ x 13″ Opal White Glass, nickel-plated support rod, E&A 31915.
4	Fisher High Temperature Burners, AHT 2596 or E&A 19309.
4	Apparatus Supports for Fisher Burners, AHT 2599.
6	Clamps, cataloy, cadmium plated with 1½-inch effective jaw opening, E&A 20195.
3	Heffman Pinchcocks, ¾″ x 1⅛″, AHT 3270, CSC 12195, or E&A 20294.
6	Mohr Pinchcocks, ⅝-inch opening, AHT 3278 or E&A 20298.
2	Test tube Clamps AHT 3246.
	Non-absorbent Cotton (1 pound).
	Corks, first quality, assorted in sizes No. 1 to No. 14, E&A 2119 (1 gross).
	Cork Borers (1 set 3/16 inch to 13/32 inch), AHT 4068, E&A 21213, or CSC 12465.
6	Vitreosil Opaque Fused Silica Dishes, 100 ml. E&A 22000.
3	Vitreosil High Form Opaque Fused Silica Crucibles, without covers, E&A 21248.
24	No. 270 Coors Porcelain Gooch Crucibles, Size No. 3 (25 ml. capacity) without covers.
4	Crucible Holders, Walter, E&A 23050, to fit the filter flasks, Item No. 38.
4	500 ml. No. 5340 Pyrex Filter Flasks.
1	Crucible Tongs, nickel-plated brass, 12 inches long, E&A 32553.
1	Crucible Tongs, nickel-plated brass, 16 inches long, AHT 9701.
1	Crucible Tongs, cast brass, 8 inches long, AHT 9692.
	Cylinders, single graduated Pyrex, AHT 4409, E&A 21652, CSC 16140.
2	1000 ml. capacity
1	500 ml. capacity
6	100 ml. capacity
2	50 ml. capacity
	Whatman No. 2 Filter Paper—15 cm. diameter (6 boxes).
	Grey Filter Paper, 33 cm. diameter, E&A 23156 (* pkgs.).
12	5-inch Triangular Files, AHT 5083.
12	Pyrex Erlenmeyer Flasks, 250 ml. No. 4980.
	Volumetric Flasks, resistance glass with ground glass stop-

pers (two graduations to contain and deliver), AHT 5465.

1 1000 ml. capacity
1 500 ml. capacity
1 250 ml. capacity
1 100 ml. capacity

Funnels, Glass, ground rim and thin stem about 10 cm. long ground to a point, AHT 5570, E&A 23622.

4 6.5 cm. diameter
2 10 cm. diameter.

1 Ribbed-Glass Funnel, 18 cm. O.D. of rim, E&A 23632, AHT 5584.

2 No. 430 Coors Porcelain Evaporating Dishes, Size No. 2, 120 ml. capacity.

12 Glass Stirring Rods, 3/16", E&A 24562.

Glass Tubing, soft glass, regular wall, E&A 24570.
5 mm. O.D. (2 lbs.)
7 mm. O.D. (2 lbs.)
8 mm. O.D. (2 lbs.)

1 No. 520 Coors Porcelain Mortar & Pestle, Size No. 2 (115 mm. inside diameter).

1 No. 550 Coors Porcelain Spot Plate, Size No. 00 (92 x 112 mm.).

1 No. 624 Coors Porcelain Pipette Rest.

No. 650 Coors Porcelain Spatulas.

1 Size 2, 142 mm. long
1 Size 4, 195 mm. long

1 Bottle Cenco Ceramic Marking Ink, CSC 14000.

No. 37000 Exax Blue Line Transfer Pipettes.

2 10 ml. capacity
3 25 ml. capacity
2 50 ml. capacity

No. 37020 Exax Blue Line Mohr-type Measuring Pipettes.

2 1 ml. capacity
2 2 ml. capacity
2 5 ml. capacity
6 10 ml. capacity

1 Pipette Support, revolving, of hardwood, with 3 decks revolving on wooden base, AHT 8264.

Rubber Tubing, Best Heavy White Wall, ½" x ⅛", for automatic still connections, E&A 30683 (12 ft.).

Rubber Tubing, Heavy Red Wall, ⅜" x ⅛", E&A 30703 (12 ft.).

Rubber Tubing, Heavy Red Wall, ¼" x 3/32", E&A 30703 (12 ft.).

Rubber Tubing, ¼" Extra Heavy Vacuum for vacuum pump and aspirator connections, E&A 30710 (12 ft.).

6 Rubber Policemen, 3/16 inch, E&A 30734.

Rubber Stoppers, Solid, No. 3, No. 4, No. 5, No. 6, No. 7, No. 8, No. 9, No. 10, E&A 30639 (1 lb. of each).

Rubber Stoppers, One-Hole, No. 3, No. 4, No. 5, and No. 6, E&A 30641 (½ lb. of each).

Rubber Stoppers, Two-Hole, No. 3, No. 4, No. 5 and No. 6, E&A 30643 (½ lb. of each).

1 Scissors (7-inch), of good quality.

1 Chapman Filter Pump, 5⅜ inches long, AHT 5286, E&A 30134.

1 Test Tube Support, double deck with 24 holes, 22 mm. diameter, with row of pins in rear, AHT 9509 or E&A 31991/1.

2 Spatulas—4-inch stainless steel blades with rosewood handles, E&A 31048.

Thermometers, AHT specifications, AHT 9525.

1 Graduated— 5° C. to 200° C. (for drying oven).
1 Graduated—10° C. to 110° C. (for B.O.D. Incubator).

1 Wood Frame Thermometer, 0-120° F., E&A 32498 (for sewage temperatures).

1 10-inch Maximum and Minimum Thermometer, self-registering, best make—40° F. to 120° F., with magnet, E&A 32416 (for recording outside air temperatures).

24 No. 9800 Pyrex Test Tubes, 150 mm. x 16 mm.

6 Triangles, 2-inch sides, E&A 32648.

Watch Glasses, E&A 32850.

12 3-inch diameter
12 4-inch diameter
12 5-inch diameter

12 5" x 5" Tinned Wire Gauzes with flat asbestos centers, E&A 33090 or AHT 9995.

12 Pencils, all-red wax.

1 4-gallon Stoneware Jar, E&A 25634, AHT 6292 (for waste materials).

1 Gas Diffuser Stones, Aloxite Brand, 1-inch diameter, E&A 24167 (for aerating B.O.D. dilution water).

Gummed Labels, Dennison No. 201, No. 209, No. 217, and No. 223 (2 boxes of each).

1 Hydrometer Cylinder, 2" dia. x 15" high, E&A 21630 (for washing pipettes in cleaning solution).

Iron Rings, combined with fasteners for attaching to iron supports, E&A 30620.

2 1¼-inch I.D.
2 2-inch I.D.
2 3-inch I.D.
2 4-inch I.D.

4 Iron Supports, Medium, 20-inch rod, E&A 31879.

Coarse Glass Wool (E&A 24638), for bottom of hydrometer to prevent breakage of pipettes (4 oz.).

The approximate cost of the minor equipment items listed above is $290.00.

Reagents and Chemicals

All reagents to be chemically pure unless otherwise noted.

Quantity	
5 lbs.	Glacial Acetic Acid, c.p.
6 lbs.	Hydrochloric Acid, Spr. gr. 1.20, c.p.
7 lbs.	Nitric Acid, sp. gr. 1.42, c.p.
1 oz.	Oxalic Acid, c.p. crystal.
18 lbs.	Sulphuric Acid, tech.
9 lbs.	Sulphuric Acid, sp. gr. 1.84, c.p.
1 lb.	Aluminum Sulphate, crystal, c.p.
8 lbs.	Ammonium Hydroxide, sp. gr. 0.90, c.p.
1 lb.	Ammonium Carbonate, c.p.
1 lb.	Asbestos, short fibres, acid washed. Powminco.
5 lbs.	Calcium Chloride, calcined, porous, gran. for desiccators, tech,
1 lb.	Chloroform, pure (Squibb).
1 lb.	Copper Sulphate, crystal, c.p.
1 lb.	Ether, Ethyl, U.S.P.
¼ lb.	Iodine, resublimed, c.p.
1 lb.	Lead Acetate, normal, c.p.
5 lbs.	Manganous Sulphate, c.p.
1 oz.	Methyl Orange Indicator.
1 oz.	Orthotolidine powder, c.p.
1 oz.	Phenolphthalein, c.p.
1 oz.	Potassium Biniodate, c.p.
1 lb.	Potassium Chromate crystals, c.p.
5 lbs.	Potassium Dichromate, tech.
1 lb.	Potassium Dichromate, c.p.
1 lb.	Potassium Hydroxide, pellets, c.p.
2 lbs.	Potassium Iodide, crystal, c.p., Bakers Analyzed Special.
1 lb.	Potassium Oxalate Neutral, c.p.
1 lb.	Potassium Permanganate, crystal, c.p.
1 oz.	Silver Nitrate, c.p.
1 lb.	Soda Lime, 4 to 8 mesh.
5 lbs.	Sodium Bicarbonate, crystal, c.p.
1 lb.	Sodium Carbonate, c.p.
5 lbs.	Sodium Chloride, crystal, c.p.
10 lbs.	Sodium Hydroxide, pellets, c.p.
1 lb.	Sodium Acid Sulphite, $NaHSO_3$, c.p.
4 oz.	Soluble Starch, Indicator Grade.
1 doz.	Litmus Paper, 6 red and 6 blue.
1 oz.	Stopcock Grease.
1 lb.	Sodium Oxalate, c.p.
5 lbs.	Sodium Thiosulphate.
¼ lb.	Thymol (to be used as a preservative for Sodium Thiosulphate Solutions).

One quart of pure Ethyl Alcohol should be purchased locally, as the chemical supply houses are not licensed to supply grain alcohol.

The approximate cost of the reagents and chemicals listed above is $60.00.

Summary of Costs

The approximate cost of furnishing and equipping the complete sewage treatment plant laboratory described above is as follows:

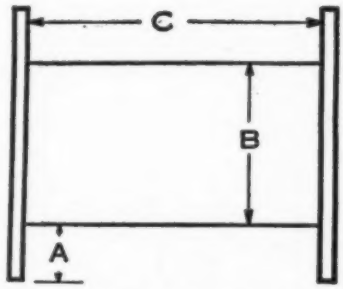
1.	Laboratory Furniture	$1,250.00
2.	Permanent Apparatus	1,110.00
3.	Minor Equipment Items	290.00
4.	Reagents and Chemicals	60.00
	Total Cost	$2,710.00

Acknowledgment is given to Mr. Joseph Boreiszo, plant chemist at the Rahway Valley Sewage Treatment Plant, for many helpful suggestions in the preparation of this article.

EQUATION OF PIPES

It is frequently desired to know what number of pipes of a given size are equal in carrying capacity to one pipe of a larger size. At the same velocity of flow the volume delivered by two pipes of different sizes is proportional to the squares of their diameters; thus one 4-inch pipe will deliver the same volume as four 2-inch pipes. With the same head, however, the velocity is less in the smaller pipe, and the volume delivered varies about as the square root of the fifth power. This table is calculated on this basis. The figures opposite the intersection of any two sizes is the number of the smaller-sized pipes required to equal one of the larger; thus one 4-inch equals 5.7 two-inch.

Dia. in.	1	2	3	4	5	6	7	8	10	12	14	16	18	20	24	30	36
2	5.7	1.															
3	15.6	2.8	1.														
4	32.	5.7	2.1	1.													
5	55.9	9.9	3.6	1.7	1.												
6	88.2	15.6	5.7	2.8	1.6	1.											
7	130.	22.9	8.3	4.1	2.3	1.5	1.										
8	181.	32.	11.7	5.7	3.2	2.1	1.4	1.									
10	316.	55.9	20.3	9.9	5.7	3.6	2.4	1.7	1.								
11	401.	70.9	25.	12.5	7.2	4.6	3.1	2.2	1.3								
12	499.	88.2	32.	15.6	8.9	5.7	3.8	2.8	1.6	1.							
13	609.	108.	39.1	19.	10.9	7.1	4.7	3.4	1.9	1.2							
14	733.	130.	47.	22.9	13.1	8.3	5.7	4.1	2.3	1.5	1.						
15	787.	154.	55.9	27.2	15.6	9.9	6.7	4.8	2.8	1.7	1.2						
16		181.	65.7	32.	18.3	11.7	7.9	5.7	3.2	2.1	1.4	1.					
17		211.	76.4	37.2	21.3	13.5	9.2	6.6	3.8	2.4	1.6	1.2					
18		243.	88.2	43.	24.6	15.6	10.6	7.6	4.3	2.8	1.9	1.3	1.				
19		278.	101.	49.1	28.1	17.8	12.1	8.7	4.8	3.2	2.1	1.5	1.1				
20		316.	115.	55.9	32.	20.3	13.8	9.9	5.7	3.6	2.4	1.7	1.3	1.			
22		401.	146.	70.9	40.6	25.7	17.5	12.5	7.2	4.6	3.1	2.2	1.7	1.3			
24		499.	181.	88.2	50.5	32.	21.8	15.6	8.9	5.7	3.8	2.8	2.1	1.6	1.		
30								27.2	15.6	10.0	6.7	4.8	3.6	2.8	1.75	1.0	
36									24.6	15.6	10.6	7.6	5.7	4.3	2.76	1.6	1.0



FORMULA:— $L = (A + B) \times A \times C \times K$

L = Length of rope in feet.

A = Depth of flange in inches. In computing capacity of reels "A" is reduced 1½" to 2" to provide for a clearance.

B = Diameter of drum in inches.

C = Width of drum in inches.

K = Constant which is given below for a given size of rope.

Rope Dia.	Value of "K"	Rope Dia.	Value of "K"
1/32	266.24	7/8	.342
1/16	66.56	1	.262
3/32	29.76	1 1/8	.207
1/8	16.64	1 1/4	.167
5/32	10.76	1 3/8	.138
3/16	7.44	1 1/2	.116
1/4	4.16	1 5/8	.099
5/16	2.67	1 3/4	.085
3/8	1.86	1 7/8	.074
7/16	1.37	2	.066
1/2	1.05	2 1/8	.058
9/16	.828	2 1/4	.052
5/8	.672	2 3/8	.046
3/4	.465	2 1/2	.042

DETERMINING YARDAGE ON REELS OR DRUMS

Although the formula was designed for computing the length of cable, etc., of various diameters, which a reel or drum of given dimensions will accommodate, the method is equally valuable for determining footage remaining on a reel or drum, for inventory purposes or other reasons. In such instances the depth (A) is the depth (in inches) of rope, cable, wire, etc., remaining on the drum or reel.

Example: Assume a reel having a 5 in. core (B) and a width of 10 in. (C). The material is ¼ in. in diameter and its depth on the core is 2 in. (A).

$$(B + A) \times A \times C = X$$
$$(5 + 2) \times 2 \times 10 = 140$$

Now refer to table of factors for the "K" value for ¼ in. materials, such being 4.16 ∴ The footage is $140 \times 4.16 = 582$ ft. or, if ½ in. material $140 \times 1.05 = 147$ ft.

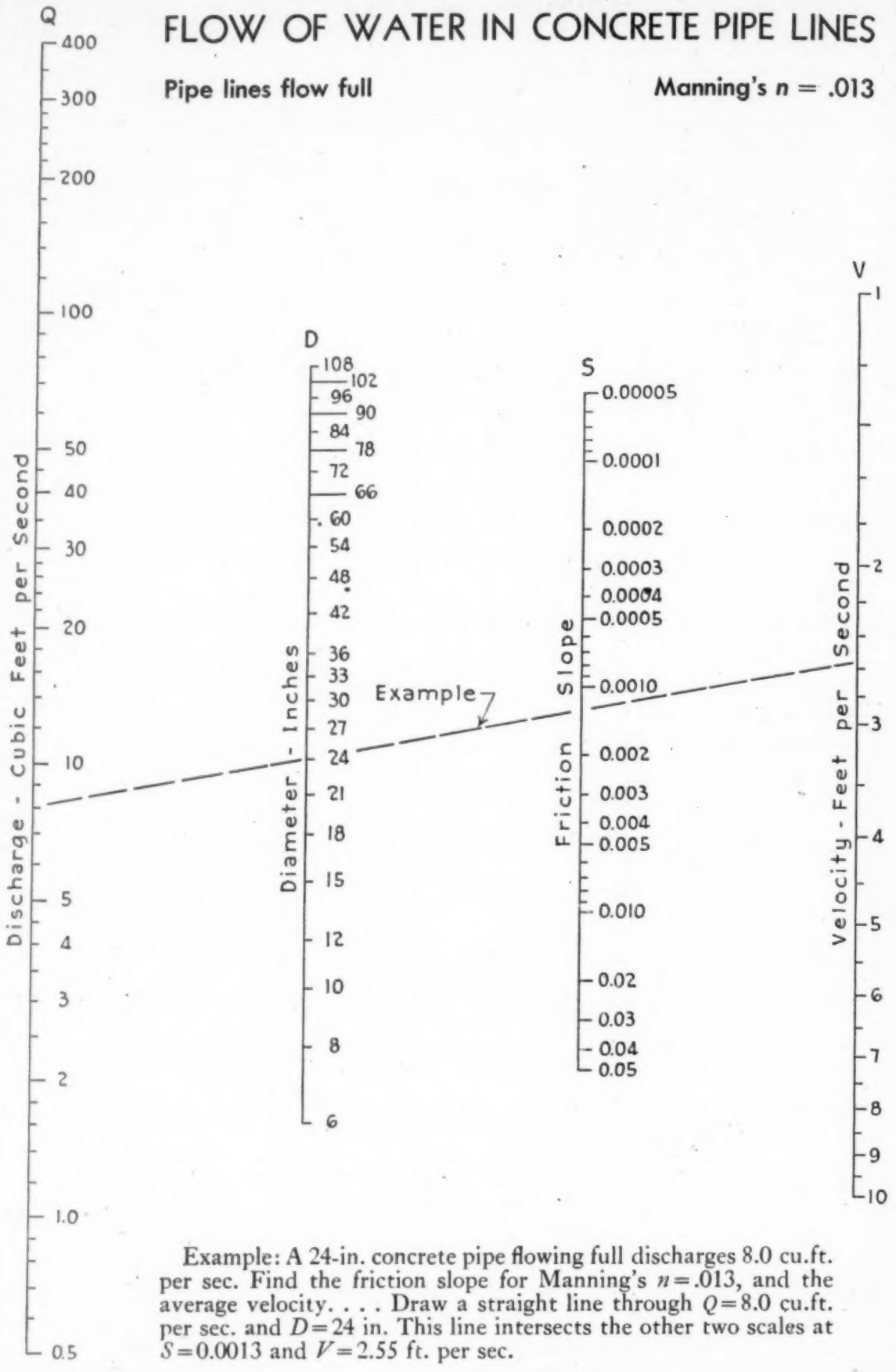
If it is desired to determine the length of rope, wire, rubber hose, copper tubing, packing, caulking yarn, etc., wound on a drum or reel, the accompanying formula will prove very helpful.

The sketch, with formula and factors, appeared in Wire Rope Cat. No. 20 of the Hazard Wire Rope Div. of American Chain and Cable Co. Inc.

FLOW OF WATER IN CONCRETE PIPE LINES

Pipe lines flow full — **Manning's n = .013**

FLOWS THROUGH CONCRETE PIPE

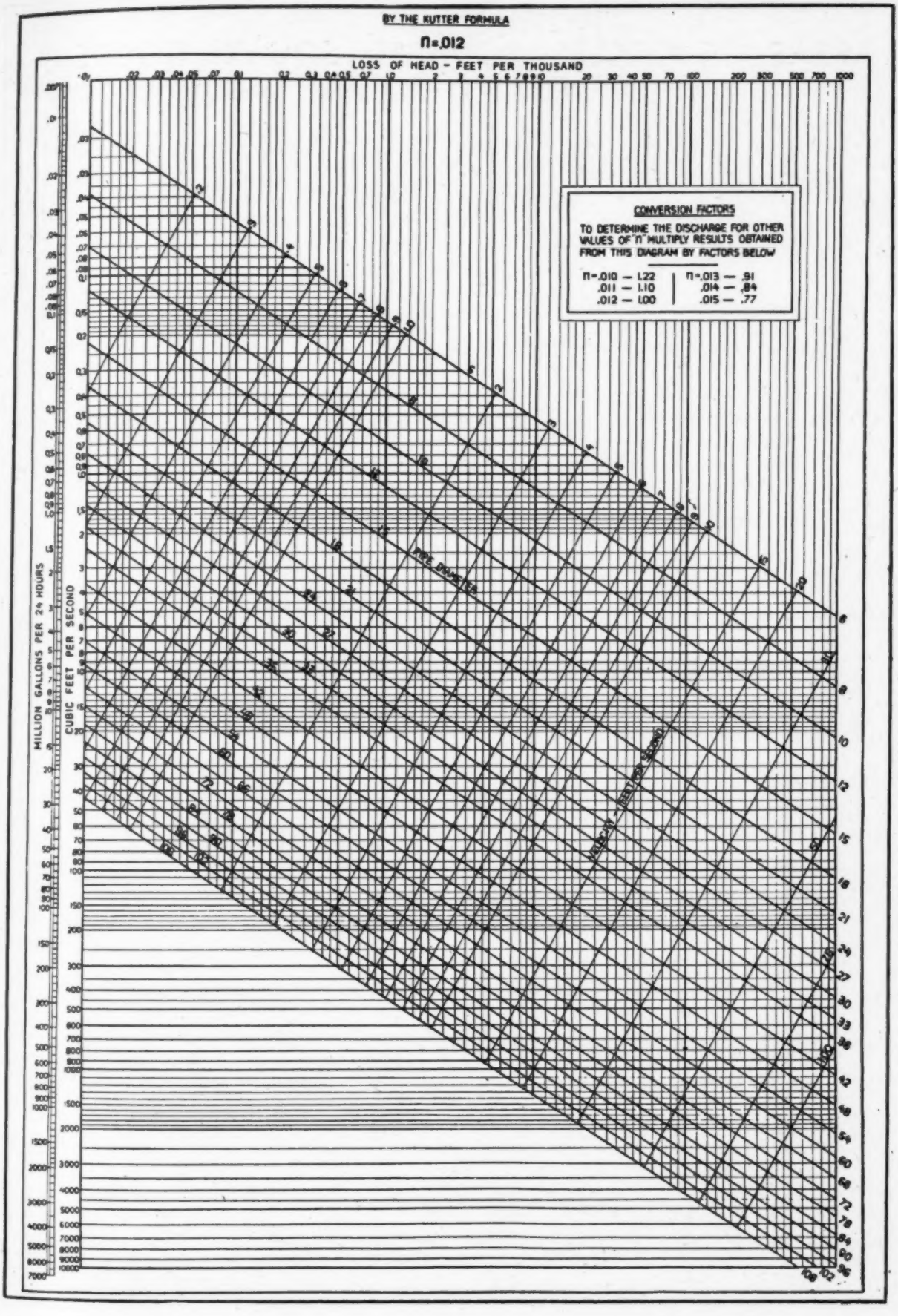


Example: A 24-in. concrete pipe flowing full discharges 8.0 cu.ft. per sec. Find the friction slope for Manning's n=.013, and the average velocity. . . . Draw a straight line through Q=8.0 cu.ft. per sec. and D=24 in. This line intersects the other two scales at S=0.0013 and V=2.55 ft. per sec.

A chart constructed by Dr. F. T. Mavis, head Dept. of Civil Engineering, Penna. State College and appearing with the chapter "Flow of Water In Pipe Lines" by Professor J. E. Christiansen, University of California, written for "Concrete Pipe Lines," published by the American Concrete Pipe Association, 1942.

**Methods of constructing this type of chart are explained in detail in "The Construction of Nomographic Charts," by F. T. Mavis. Published by International Textbook Company, Scranton, Pa., 1939.*

FLOWS THROUGH CONCRETE PIPE


BY THE KUTTER FORMULA
n=.012
LOSS OF HEAD - FEET PER THOUSAND
MILLION GALLONS PER 24 HOURS
CUBIC FEET PER SECOND
PIPE DIAMETER
VELOCITY IN FEET PER SECOND
CONVERSION FACTORS
TO DETERMINE THE DISCHARGE FOR OTHER VALUES OF "n" MULTIPLY RESULTS OBTAINED FROM THIS DIAGRAM BY FACTORS BELOW
n=.010 — 1.22
.011 — 1.10
.012 — 1.00
n=.013 — .91
.014 — .84
.015 — .77

A graph developed by N. D. Whitman, late Consulting Engineer of Los Angeles, appearing in "Concrete Pipe Lines," published by the American Concrete Pipe Association in 1942.

**Methods of constructing this type of chart are explained in detail in "The Construction of Nomographic Charts," by F. T. Mavis. Published by International Textbook Company, Scranton, Pa., 1939.*

AREAS OF CIRCLES—SQUARES—SQUARE ROOTS

(Also Fractions to Decimal Equivalent.)

No. N Fraction	No. N Decimal	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
1/16	.0625	.0039	.2500	.0031
1/8	.125	.0156	.3536	.0125
3/16	.1875	.0352	.4330	.0276
1/4	.25	.0625	.5000	.0491
5/16	.3125	.0977	.5590	.0767
3/8	.375	.1406	.6124	.1105
7/16	.4375	.1914	.6614	.1503
1/2	.50	.2500	.7071	.1964
9/16	.5625	.3164	.7500	.2485
5/8	.625	.3906	.7906	.3068
11/16	.6875	.4727	.8297	.3712
3/4	.75	.5625	.8660	.4418
13/16	.8125	.6602	.9014	.5185
7/8	.875	.7656	.9354	.6013
15/16	.9375	.8789	.9683	.6903
1	1.	1.000	1.000	.7854
1 1/8	1.125	1.266	1.061	.9940
1 1/4	1.25	1.563	1.118	1.227
1 3/8	1.375	1.891	1.175	1.485
1 1/2	1.50	2.250	1.225	1.767
1 5/8	1.625	2.641	1.275	2.074
1 3/4	1.75	3.063	1.323	2.405
1 7/8	1.875	3.516	1.369	2.761
2	2.	4.000	1.414	3.142
2 1/8	2.125	4.516	1.458	3.547
2 1/4	2.25	5.063	1.500	3.976
2 3/8	2.375	5.641	1.541	4.430
2 1/2	2.50	6.250	1.581	4.909
2 5/8	2.625	6.891	1.620	5.412
2 3/4	2.75	7.563	1.658	5.940
2 7/8	2.875	8.266	1.696	6.492
3	3.	9.000	1.732	7.069
3 1/8	3.125	9.766	1.768	7.670
3 1/4	3.25	10.56	1.803	8.296
3 3/8	3.375	11.39	1.837	8.946
3 1/2	3.50	12.25	1.871	9.621
3 5/8	3.625	13.14	1.904	10.32
3 3/4	3.75	14.06	1.937	11.04
3 7/8	3.875	15.02	1.969	11.79
4	4.	16.00	2.000	12.57
4 1/8	4.125	17.02	2.031	13.36
4 1/4	4.25	18.06	2.062	14.19
4 3/8	4.375	19.14	2.092	15.03
4 1/2	4.50	20.25	2.121	15.90
4 5/8	4.625	21.39	2.151	16.80
4 3/4	4.73	22.56	2.180	17.72
4 7/8	4.875	23.77	2.208	18.67
5	5.00	25.00	2.236	19.64
5 1/4	5.25	27.56	2.291	21.65
5 1/2	5.50	30.25	2.345	23.76
5 3/4	5.75	33.06	2.398	25.97
6	6.	36.00	2.450	28.27
6 1/4	6.25	39.06	2.500	30.68
6 1/2	6.50	42.25	2.550	33.18
6 3/4	6.75	45.56	2.598	35.78
7	7.	49.00	2.646	38.48
7 1/4	7.25	52.56	2.693	41.28
7 1/2	7.50	56.25	2.739	44.18
7 3/4	7.75	60.06	2.784	47.17
8	8.00	64.00	2.828	50.27
8 1/4	8.25	68.06	2.872	53.46
8 1/2	8.50	72.25	2.916	56.75
8 3/4	8.75	76.56	2.958	60.13
9	9.00	81.00	3.000	63.62
9 1/4	9.25	85.56	3.041	67.20
9 1/2	9.50	90.25	3.082	70.88
9 3/4	9.75	95.06	3.123	74.66

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
10	100	3.162	78.54
11	121	3.317	95.03
12	144	3.464	113.1
13	169	3.606	132.7
14	196	3.742	153.9
15	225	3.873	176.7
16	256	4.000	201.1
17	289	4.123	227.0
18	324	4.243	254.5
19	361	4.359	283.5
20	400	4.472	314.2
21	441	4.583	346.4
22	484	4.690	380.1
23	529	4.796	415.5
24	576	4.899	452.4
25	625	5.000	490.9
26	676	5.099	530.9
27	729	5.196	572.6
28	784	5.292	615.8
29	841	5.385	660.5
30	900	5.477	706.9
31	961	5.568	754.8
32	1024	5.657	804.2
33	1089	5.745	855.3
34	1156	5.831	907.9
35	1225	5.916	962.1
36	1296	6.000	1017.9
37	1369	6.083	1075.2
38	1444	6.164	1134.1
39	1521	6.245	1194.6
40	1600	6.325	1256.7
41	1681	6.403	1320.3
42	1764	6.481	1385.4
43	1849	6.557	1452.2
44	1936	6.633	1520.5
45	2025	6.708	1590.4
46	2116	6.782	1661.9
47	2209	6.856	1734.9
48	2304	6.928	1809.6
49	2401	7.000	1885.7
50	2500	7.071	1936.5
51	2601	7.141	2042.8
52	2704	7.211	2123.7
53	2809	7.280	2206.2
54	2916	7.349	2290.2
55	3025	7.416	2375.8
56	3136	7.483	2463.0
57	3249	7.500	2551.8
58	3364	7.616	2642.1
59	3481	7.681	2734.0
60	3600	7.746	2827.4
61	3721	7.810	2922.5
62	3844	7.874	3019.1
63	3969	7.937	3117.2
64	4096	8.000	3217.0
65	4225	8.062	3318.3
66	4356	8.124	3421.2
67	4489	8.185	3525.7
68	4624	8.246	3631.7
69	4761	8.307	3739.3
70	4900	8.367	3848.5
71	5041	8.426	3959.2
72	5184	8.485	4071.5
73	5329	8.544	4185.4
74	5476	8.602	4300.8
75	5625	8.660	4417.9

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
76	5776	8.718	4536.5
77	5929	8.775	4656.6
78	6084	8.832	4778.4
79	6241	8.888	4901.7
80	6400	8.944	5026.5
81	6561	9.000	5153.0
82	6724	9.055	5281.0
83	6889	9.110	5410.6
84	7056	9.165	5541.8
85	7225	9.220	5674.5
86	7396	9.274	5808.8
87	7569	9.327	5944.7
88	7744	9.381	6082.1
89	7921	9.434	6221.1
90	8100	9.487	6361.7
91	8281	9.539	6503.9
92	8464	9.592	6647.6
93	8649	9.644	6792.9
94	8836	9.695	6939.8
95	9025	9.747	7088.2
96	9216	9.798	7238.2
97	9409	9.849	7389.8
98	9604	9.900	7543.0
99	9801	9.950	7697.7
100	10000	10.00	7854.0
101	10201	10.05	8011.9
102	10404	10.10	8171.3
103	10609	10.15	8332.3
104	10816	10.20	8494.9
105	11025	10.25	8659.0
106	11236	10.30	8824.7
107	11449	10.34	8992.0
108	11664	10.39	9160.9
109	11881	10.44	9331.3
110	12100	10.49	9503.3
111	12321	10.54	9676.9
112	12544	10.58	9852.0
113	12769	10.63	10029
114	12996	10.68	10207
115	13225	10.72	10387
116	13456	10.77	10568
117	13689	10.82	10751
118	13924	10.86	10936
119	14161	10.91	11122
120	14400	10.95	11310
121	14641	11.00	11499
122	14884	11.05	11690
123	15129	11.09	11882
124	15376	11.14	12076
125	15625	11.18	12272
126	15876	11.23	12469
127	16129	11.27	12668
128	16384	11.31	12868
129	16641	11.36	13070
130	16900	11.40	13273
131	17161	11.45	13478
132	17424	11.49	13685
133	17689	11.53	13893
134	17956	11.58	14103
135	18225	11.62	14314
136	18496	11.66	14527
137	18769	11.70	14741
138	19044	11.75	14957
139	19321	11.79	15175
140	19600	11.83	15394
141	19881	11.87	15615

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
142	20164	11.92	15837
143	20449	11.96	16061
144	20736	12.00	16286
145	21025	12.04	16583
146	21316	12.08	16742
147	21609	12.12	16972
148	21904	12.17	17203
149	22201	12.22	17437
150	22500	12.25	17671
151	22801	12.29	17908
152	23104	12.33	18146
153	23409	12.37	18385
154	23716	12.41	18627
155	24025	12.45	18869
156	24336	12.49	19113
157	24649	12.53	19359
158	24964	12.57	19607
159	25281	12.61	19856
160	25600	12.65	20106
161	25921	12.69	20358
162	26244	12.73	20613
163	26569	12.77	20867
164	26896	12.81	21124
165	27225	12.85	21382
166	27556	12.88	21642
167	27889	12.92	21904
168	28224	12.96	22168
169	28561	13.00	22432
170	28900	13.04	22698
171	29241	13.08	22966
172	29584	13.11	23235
173	29929	13.15	23506
174	30276	13.19	23779
175	30625	13.23	24053
176	30976	13.27	24328
177	31329	13.30	24606
178	31684	13.34	24885
179	32041	13.38	25165
180	32400	13.42	25447
181	32761	13.45	25730
182	33124	13.49	26016
183	33489	13.53	26302
184	33856	13.56	26590
185	34225	13.60	26880
186	34596	13.64	27172
187	34969	13.67	27465
188	35344	13.71	27759
189	35721	13.75	28055
190	36100	13.78	28353
191	36481	13.82	28652
192	36864	13.86	28953
193	37249	13.89	29255
194	37636	13.93	29559
195	38025	13.96	29865
196	38416	14.00	30172
197	38809	14.04	30481
198	39204	14.07	30791
199	39601	14.11	31103
200	40000	14.14	31416
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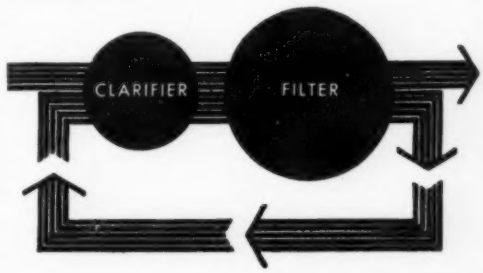

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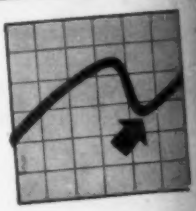

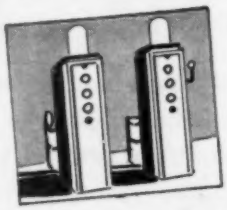

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